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ABSTRACT

This theme issue highlights the diversity of reform initiatives in order to provide a deep understanding of the complexities associated with educational reform in general and the reform of science education in particular. Systemic reform initiatives at the national and state levels along with locally-inspired efforts at reform are outlined. Articles include: "The Hidden Variable: How Organizations Influence Teacher Responses to Secondary Science Curriculum Reform" (Larry Cuban); "Is Systemic Reform the Answer for Schools and Science Education? Cautions from the Field" (James Joseph Scheurich and Edward Fuller); "Who Systematizes the Systematizers? Policy and Practice Interactions in a Case of State-Level Systemic Reform" (Reba Page); "The Rhetoric and Reality of Systemic Reform: A Critique of the Proposed National Science Education Standards" (Robert Donmoyer); "Inviting Adolescents into Academic Communities: An Alternative Perspective on Systemic Reform" (Lauren A. Sosniak); "Learning Environments as a Site of Science Education Reform" (Shirley Magnusson and Annemarie Palincsar); "Navigating Change in High School Science and Mathematics: Lessons Teachers Taught Us" (Patricia Wasley, Robert Donmoyer, and Laura Maxwell); "The Battle to Reform Science Education: Notes from the Trenches" (Natalie Hiller); "Site-Based Management, Shared Decision Making, and Science and Mathematics Education: A Tale of Two Districts" (Juanita Wagstaff); and "Reforming Science Education To Include Girls" (Charol Shakeshaft). (JRH)

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Reforming Science Education

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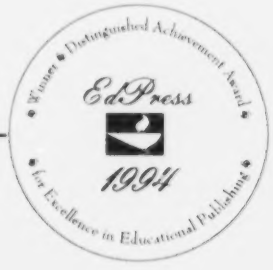

Next Issue: Learning From Student Voices

This Issue

THERE IS A GROWING CONSENSUS in this country that American schools are in trouble and badly in need of reform. No area of the school curriculum has received more attention by reformers than the area of science. This heightened level of interest in the teaching and learning of science is understandable. After all, science education directly impacts national security and this country's ability to remain preeminent in the economic sphere. Scientific understanding is also increasingly required for making informed policy decisions. Therefore in a democracy, a high degree of scientific literacy is needed even for ordinary citizens.

As a consequence of these concerns, we have seen in recent years a plethora of initiatives to reform science curriculum and teaching, as well as other aspects of the system believed to influence the teaching and learning of science. The organizational change strategies embraced by these different reform initiatives are diverse and, at times, seemingly contradictory.

Some initiatives such as school restructuring and shared decision making are generic in nature and do not specifically focus on science education reform. Other initiatives directly target curriculum and instruction in science classrooms. Within this latter group, some initiatives are built around action at the national or state levels; others are built around grass-roots action; still others reject the traditional top-down/bottom-up dichotomy and claim to synthesize approaches that, in the past, were seen as antithetical.

The conceptions of teaching, learning, and curriculum that undergird reformers' thinking are as diverse as their conceptions of organizational change. When one looks at the literature on science education reform, for instance, one sees long lists of predefined outcomes, sometimes referred to as *benchmarks* and at other times as *standards*. (In the past they probably would have been called *competencies* or *objectives*.) But there is also talk of (a) the need for children to be self-directed learners who define for themselves topics and problems to be investigated and learned and (b) the need for teachers to engage in a more improvisational sort of teaching, the sort of teaching that can respond to students' needs and interests. Often these views—which historically have been seen as antithetical—are included within a single reform initiative.

The National Center for Science Teaching and Learning (NCSTL), a research organization established in 1991 with a $6.93 million grant from The Office of Educational Research and Improvement of the U.S. Department of Education, has attempted to study a diverse sample of science education reform efforts. The goal of this particular research initiative, which I have overseen for the past 4 years, has been two-fold: (a) to develop a storehouse of context-rich case material that will provide a deep understanding of the complexities associated with educational reform in general and the reform of science education in particular and (b) to make some more general, theoretical sense of what we have learned from studying particular cases of reform.

In this issue, we share some of what we have learned. The diversity of the reform initiatives discussed confirms that we have met our first goal. Here you will read about systemic reform initiatives at the national and state levels, but you will also read about more locally-inspired efforts at reform.

We have been particularly concerned about representing the views of teachers, the individuals who we will ultimately have to rely on to implement any ideas reformers develop. In one article, a teacher who has been involved with a large number of reform projects (including a project sponsored jointly by the NCSTL and the Coalition of Essential Schools) speaks for herself about what various efforts to reform science education look like from the perspective of the classroom. We have also tried to provide a historical perspective, to insure that we are not simply reinventing the wheel when we attempt to reform science education and, in particular, to make sure that the problems of the past are not repeated in the present. The lead article in this issue, in fact, analyzes why past efforts to reform science education were less than successful.

As this issue is being prepared, we are more or less at a midway point in our attempt to move from the study of particular reform initiatives to the construction of more general theoretical understandings about the process of science education reform. The articles in this issue, for the most part, reflect this state of affairs. You will read about particular cases; but you will also find attempts to draw out of the particulars more general concepts and insights that can be used heuristically to look at and think about a whole range of educational reform strategies. Given the complexity of the phenomena we have investigated and the failure to find neat and tidy theoretical solutions to the messy problems of practice in the past, this halfway house between theory and practice in which we are situated may, indeed, be a rather useful place from which to view the problems and possibilities associated with reforming science education.

Robert Donmoyer
Editor

Larry Cuban

The Hidden Variable: How Organizations Influence Teacher Responses to Secondary Science Curriculum Reform

For over a century, there have been continuous efforts to alter both the content of science education and how it is presented to secondary school pupils. In the closing decade of the 19th century, for example, the prestigious National Educational Association's Committee of Ten, endorsing a science subcommittee's report largely produced by university science faculty, recommended that the secondary science curriculum be formally arranged into separate subjects such as biology, physics, and chemistry. That occurred in the following decades (National Educational Association, 1893).[1]

Shortly afterward, another generation of curricular reformers, driven by new ideas about the integration of subjects, linkages with the community, teaching to build pupils' understanding and reasoning, and the role of school in improving society, tried to overhaul secondary school science content and teaching. By the 1930s, the ideas of these progressive educators had become mainstream thinking, particularly in urban schools (Hurd, 1949; *Thirty Schools*, 1942).

In the early 1950s, another renovation of the science curriculum, midwifed into existence by the National Science Foundation and sped along by the Cold War, lasted into the early 1970s. As with the earlier reforms driven by the Committee of Ten, academics interested in modernizing science content authored new courses and textbooks. Its success in altering both the subject matter and practice of teachers continues to be debated by scholars today (Aikin & House, 1981; Dow, 1991; Welch, 1979).[2]

Finally, in the early 1980s, prompted by a series of national reports on the perceived deterioration of public schools, a number of projects have sought to alter science curriculum and instruction across the nation. Again, university academics have dominated the commissions but far more practitioners and informed citizens have participated in the curricular deliberations than in earlier reform movements (AAAS, 1989; West, 1992).

In this swift trip through the last century of reform in science curriculum, two distinct purposes have vied for attention: to have students know bodies of organized scientific knowledge, and to create a science for living. Of the two aims, the former has dominated curricula since the late 19th century, although the latter purpose has been evident in periodic bursts of reform, especially during the early decades of this century. The dominance of content divided into scientific disciplines is (and has been) obvious in most secondary schools where science subjects are separately taught in 45- to 50-minute periods, and teacher-centered instruction is geared to dispensing scientific information to large groups of students.

The quest to link scientific knowledge to daily life—the second purpose—emerged strongly in the curriculum during the progressive education impulse earlier in this century and occasionally penetrated

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classrooms. Places that experimented with reorganizing their school, revising schedules, and inventing curriculum linkages between classrooms and daily life differed substantially from most secondary schools. And in the 1990s, there is another, almost neoprogressive, impulse in the science curriculum toward linking scientific content to daily life (AAAS, 1989; Aikin, 1942; Newman, 1990).

This brief description raises at least one puzzling question: Why did reformers in the past committed to the purpose of creating a science for living find it so difficult to alter the prevailing patterns? This question has many possible answers ranging from the accumulated weight of traditional views of knowledge and teaching to the adequacy of resources, who the students were, the presence or absence of leadership, or to schools merely doing what their patrons wanted done. These are plausible answers and, for some, even convincing ones. However, in preparing this analysis of science curriculum reform, I note one other plausible explanation missing from the literature on improving science curricula in the last century: the influence of district, school, and classroom organization upon what knowledge is taught and how it is presented. Examining this factor may suggest to a current generation of reformers reasons why so many curricular reforms in the past ebb and dissolve over time.

The answer I have constructed to make sense of these repeated efforts to improve secondary school science curriculum and classroom instruction is straightforward:

1. Past and current curricular policies require district, school, and classroom organization to transform information and ideas into teaching practices.

2. The constraints of district, school, and classroom organizations (including cultures) shape to a large degree, but do not wholly determine, how teachers teach science.

3. Coping with these organizational constraints, teachers have invented a practical pedagogy that is tailored to fit their beliefs and classroom practices.

4. Hence, to substantially change current science curriculum and instruction will require shifts in district, school, and classroom organization, culture, and teacher beliefs.

This answer assumes that there is not one but four science curricula in secondary schools that need inspection. The *official* curriculum is what state and district officials set forth in curricular frameworks and courses of study. They expect teachers to teach it; they assume students will learn it. These official curricula increasingly are aligned with state-approved textbooks that teachers are directed to use and state-mandated tests that teachers must administer.

But teachers, working alone in their rooms, choose what to teach and how to present it. Their choices derive from their knowledge of the subject they teach, their experiences in teaching the content, their affection or dislike for topics, and their attitudes toward the students they face daily. In fact, researchers continually find that teachers in the same building will teach different versions of the same course. Thus, the official curriculum and what teachers teach may overlap in the title of the course, certain key topics, and the same text, but can differ substantially in actual subject matter and teaching methods. The *taught* curriculum, then, differs from the official curriculum (Hawthorne, 1992; Oakes, 1985; Page, 1991).

The taught curriculum overlaps with but differs significantly from the *learned* curriculum, or what students learn. Results from paper-and-pencil tests certainly capture a portion of what students learn in a class. Beyond what test scores reveal about learning, students learn to recite, review material, locate sources, seek help, avoid teachers' intrusiveness, and how to act attentive. Collateral learnings, in Dewey's phrase, occur when children pick up ideas from classmates, copy their teachers' habits and ties, imitate their humor or sarcasm, or strive to be as autocratic or democratic as the adults. Thus the learned curriculum differs from the official and taught curricula (Dreeben, 1973; Fenstermacher, 1986).

And what students learn does not exactly mirror what is in the *tested* curriculum. Classroom, school, district, state, and national tests, often using multiple-choice and other short-answer items, do, indeed, capture some of the official and taught curricula. To the degree that teachers attend to such tests, portions of the official and taught curricula merge. But what is tested is a limited part of what is intended by policymakers, taught by teachers, and learned by students. Since so many of these tests seek to sort high achieving students from their lower-achieving peers, the information, ideas, and skills sought on these tests represent an even narrower band of knowledge (Madaus, 1987).

Thus, there are four curricula, not one. Many policymakers and administrators engaged in science

curriculum reform since the turn of the century assumed that the official, taught, learned, and tested curricula were one and the same. By the 1970s, researchers had established clearly that the official and taught differed. In the 1980s and 1990s there is far more attention paid to the taught, learned and tested curricula. I use these distinctions among curricula in elaborating the above argument (Cuban, 1990; Erickson & Shultz, 1990; Jackson, 1990).

Here, then, is an organizational and curricular framework for answering the question: Why did reformers committed to the purpose of creating a science for living find it so difficult to alter the prevailing patterns?

Organizational Influences

But why even explore organizational influences on secondary science curricula? From life experiences, each of us can easily observe that organizations matter. Anyone who has transferred from private industry to the university can talk about how different it is to work for one than the other. Army officers know how battalions in the same brigade and brigades in the same division are very different places in which to work. Similarly, for schools, how activities are organized and members of the organization are governed shapes what occurs daily.

But school organizations are different from business and the military, which have clearly defined products and outcomes: a car manufactured or a hill taken. With schools, defining what they ought to "produce" in their graduates is continually contested. How "good" teaching and "effective" learning occur is ardently debated. Moreover, school board members and their appointed administrators cannot observe directly what teachers do in their classrooms (except when principals occasionally visit) or what students learn (except by monitoring standardized tests). Thus, the technology of schooling (i.e., teaching) is divorced from common managerial controls used to monitor production elsewhere.

Here, then, are organizations that lack consensus on describing the desired product, cannot directly observe the production process, and have trouble explaining how they create products. Such organizations that cannot specify what their key staff must do or what the desired outcomes should be can be called coping organizations or institutions ruled by procedures and beliefs that conform to the expectations of those constituencies that supply political and financial support. The next section analyzes how districts, schools, and classrooms are organized institutionally and their connections to secondary science curricula (Wilson, 1989).[3]

District, School And Classroom Organization

Exactly what formal and informal organizational features affect what and how teachers teach science? In discussing organization, I include how authority is used to govern, the formal building blocks that give structure to the organization, and the informal features that influence how people behave within them, often referred to as organizational cultures. Hence, organizations, as I use the term, include governance, formal structures, cultural processes, and teaching. I begin with the district because each state, the constitutional authority that governs schooling in the United States, uses the district as its political arm to conduct schooling on a daily basis (except Hawaii where the state operates all schools).

In each district, a school board, the policymaking body responsible to the state, hires professional staff, authorizes expenditures, builds schools, sets the curriculum within broad or narrow state mandates, and determines whether its goals are being met. Historically, such decentralized governance of schooling (as compared to centralized control of schooling in European, African, and Asian nations) means about 15,000 school districts in the United States, down from a high of 130,000 in 1931 (Tyack, 1990).

The school board sets the conditions for classroom teaching. Boards determine how schools and classrooms are organized, the funding level committed to the enterprise (influenced increasingly by the availability of state funds), the official curriculum, and staff to implement that curriculum. Governance is the formal side of school boards' influence on classrooms; informally, the district's culture also shapes the degree to which a spirit of tradition or instructional improvement mark schools and classrooms.

By culture, I mean the unexamined, deeply-embedded norms and expectations that district staffs share about performing their central tasks of schooling children. These feelings, values, and patterns of behaving are often unarticulated and passed on to newcomers unobtrusively. For example, many district organizations, especially in big cities, tilt toward centralized,

hierarchical control of school operations. In such districts, major curricular, budgetary, and staffing decisions to implement school board policies often are made at headquarters and each school is expected to comply. The district culture of top-down decision making values efficiency and compliance; such values often seep into schools (McNeil, 1986; Wise, 1979). Informally, many teachers and administrators resist these values and exert discretion when they can (Weatherly & Lipsky, 1977).

Some district boards and superintendents govern schools by more decentralized procedures such as allocating resources to schools and leaving certain curricular and staffing decisions to each school's principal, faculty, or school-site council. Shared decision making at the school site is the norm in such districts. In these instances, the district prizes the values of school autonomy, professional discretion, independence, and experimentation; practitioners realize quickly that their ideas in and out of class are respected (Lightfoot, 1983; Sizer, 1992).

School Organization

A school organization can be analyzed also by its formal and informal structures. The term *structures* refers to the essential building blocks of a school that are often taken for granted; they are seen as the lakes, mountains, wind, and sun of a natural terrain. At the risk of being too obvious, I list these familiar, formal structures to point out that these are not like the wind and sun because they were quite different a century and a half ago and have been adapted to meet changing political, social, and economic needs. In short, they are made and unmade by human hands.

The age-graded school

Imported from Prussia by mid-19th century American school reformers, the age-graded school revolutionized the governance, structures, cultures, and practice of schooling and teaching. These reformers sought to restructure the then current one-room schools and the role of the teacher to fit a new vision for how an industrializing social order and political democracy could provide mass schooling.

The new age-graded, multi-room elementary school in late 19th century cities and towns upended the one-room district school. Now the school had a principal and a separate classroom for each teacher. Children were grouped by age and attended for 8-9 months a year. The subject matter of the curriculum was divided into grade-level chunks, and each year, the teacher decided who should be promoted to the next grade or be kept back for another year. These were fundamental changes in the organization and delivery of schooling (Angus, Mirel, & Vinovskis, 1988; Fuller, 1982; Tyack, 1974).

The implicit theory underlying the age-graded school is that educational quality, efficiency, and equity come from uniformity. If a teacher teaches a group of students for a certain amount of time, according to the theory, almost all of these students will learn the required amount of knowledge at roughly the same rate and will move on to the next teacher. Those who do not keep pace will take longer to learn the standard course of study.

By the early 1900s most urban school districts had reorganized their schools into age-graded schools. The new organizational form was *the* only way to design schooling and, except for sporadic (and largely failed) attempts to introduce nongraded schooling, has since remained the prevailing form of district-wide elementary and secondary school organization across the nation. How do age-graded school structures influence the actions of both adults and children in schools (Goodlad & Anderson, 1987; Kaestle, 1983; Tyack, 1974)?

Differentiated curricula, schedules, tests

The structure of age-graded schools (e.g., self-contained classrooms, a curriculum divided up into chunks for each level, 50-minute periods in secondary schools, and tests constructed by the district, school, or teacher) derived from the basic imperatives of public schooling: to manage in an orderly manner masses of students from varied backgrounds and motivations who were compelled to attend school and absorb certain knowledge.

Teacher norms and expectations also flowed from these imperatives. Because the building itself isolated teachers from one another, this further complicated monitoring and hindered collaboration; teachers came to expect little supervision. The age-graded school created norms of teacher self-reliance and solo practice. The differentiated curriculum increased the isolation.

A differentiated curriculum also refers to the varied official courses of study in comprehensive secondary schools containing three or more sets of

courses (e.g., college preparatory, commercial, vocational, and general or regular courses of study) that were packaged to appeal to students and their parents who sought varied job and career futures after graduation. Within the differentiated courses of study, separate disciplines dominated what was offered. In the college preparatory curriculum, for example, 10th graders would take biology, 11th graders chemistry, and 12th graders, physics (Bidwell & Dreeben, 1990; Krug, 1964; Oakes, 1985; Powell, Farrar, & Cohen, 1985).

To manage differentiated curricula, administrative procedures had to be put into place. The adoption of the Carnegie Unit in the early 20th century led to school administrators dividing the school day into equal chunks of time (45- to 50-minute periods). The resulting multi-period day in secondary schools made it possible for students to collect many different subjects and credits for graduation, but it played havoc with laboratory courses requiring double periods so that science labs could meet college standards (Tompkins & Gaumitz, 1954).

Teacher-made, district-designed, and state-required tests became increasingly critical milestones in a student's school career. To move from one grade to another and from one subject to another required some evidence that content and skills designated for that grade or subject had been absorbed by pupils. Test results met that need. Thus, the procedural regularities of school bells, 45-minute periods, and frequent tests grew out of the structural demands of differentiated curricula in the age-graded school. Similar regularities arose in the classroom from these formal structures.

Classroom Organization

The central feature of secondary school buildings is that they contain separate classrooms for one teacher and 25-35 students of approximately the same age who must spend about one hour daily in a room. Within this one classroom, the teacher, like colleagues in other rooms within the school, is expected to maintain control, teach certain subject matter, motivate students to learn, vary levels of instruction according to student differences, and display evidence that students have performed satisfactorily.

Considering these many demands generated by the structure of a self-contained classroom, teachers who survive beyond the initial years have learned to ration their energy and allocate their time carefully. More importantly, they have invented and polished a repertoire of teacher-centered instructional practices that have emerged as resilient, imaginative, and efficient solutions to dealing with a crowd of students in a small space for extended periods of time. They have created a practical pedagogy that reconciles the dilemma of two conflicting values: maintaining order within a classroom and getting students to learn subject matter and skills they would not ordinarily learn elsewhere. From this practical compromise, teaching regularities have arisen (Cuban, 1984; Doyle, 1986; Goodlad, 1984; Sarason, 1971).

Arranging desks into rows and using seating charts, for example, permit the teacher easy surveillance of pupils to maintain order. Teacher-established routines for students raising their hands to answer questions and to speak only when recognized by the teacher establishes a framework for whole-group instruction. Students asking permission of the teacher to leave the room silently underscores a teacher's authority and satisfies the imperative of maintaining classroom order.

Moreover, teaching the entire class at one time is simply an efficient and convenient use of the teacher's time—a valuable and scarce resource—to cover mandated content and to maintain control. Lecturing, recitation, seatwork, homework drawn from texts, and weekly tests made up of multiple choice items are other efficient, routine ways of transmitting subject matter to groups and determining whether students have learned the material. These practical regularities grow out of the larger expectations that teachers strive to meet and the demands of the classroom as a workplace. Teachers, then, learned to manage the situational dilemmas imposed by this structure, over which they had little control, by inventing creative compromises in the shape of teacher-centered instructional practices

Other pedagogical approaches, where students work alone or in small groups, move freely around the room, and leave the room and school to learn in other settings, in the minds of most teachers, disrupts classroom routines geared to efficiently handling batches of students. Of greater importance to teachers is that such student-centered activities violate many—but not all—teachers' deeply-held beliefs and values about how teaching should occur, the importance of students absorbing subject matter, and how pupils should learn.

Shifting the center of gravity from a teacher-centered classroom to one in which teachers and students share responsibility for learning is substituting one set of beliefs for another. Student-centered approaches disturb the regularities of a practical pedagogy tailored to the contours of self-contained classrooms. Such practices are incompatible with existing norms, expectations, and beliefs held by most teachers about their authority to govern and the organizational structures within which they work. Such a shift in classroom cultural values would require a complete overhaul of the teacher's roles (e.g., from captain of the ship to coach; from information-giver to question-asker) and basic modes of classroom operation (Cuban, 1993; Sizer, 1984).

School and Classroom Cultures

Of course, school and classroom practices vary. Not all schools are alike nor do all teachers teach alike. But the dominant tendencies in school and classroom regularities as I have described them are well documented. What helps account for the variation is organizational cultures and individual differences among teachers (Cuban, 1991; Goodlad, 1984; Sarason, 1971).

Culture—those deeply-ingrained, patterned responses to familiar and new situations mirroring common basic values held by group members—matters. Teaching kindergarten or high school chemistry matters. The ways high school teachers are trained in the disciplines and how they are organized into departments also matter. In elementary schools teachers are, by and large, far more willing to work together and share ideas than in high schools. There is more sensitivity to the emotional and social development of children than, again in general terms, in high schools.

For example, within high schools one dominant value among teachers is prizing the freedom to act as a solo practitioner who closes the classroom door and teaches a class unimpeded by supervisors, other teachers, or community members. When that value gets wedded to the common belief among teachers trained in subject-matter disciplines that students must learn content first before they can analyze and solve problems, instructional practices get shaped quietly and powerfully. Such values and beliefs stitched together with others make a school culture that influences both school-wide and classroom behaviors in such important matters as, for example, responding to innovations imported from outside the school (Cohen, 1989; Feiman-Nemser & Floden, 1986; Lortie, 1975).

Finally, each teacher creates a mini-culture in his or her classroom with rules for students, ceremonies, activities, and behavioral and academic expectations quietly and informally expressed. Each classroom, like each individual, becomes a distinctive personality because each teacher's experiences, beliefs, and values vary. A Jaime Escalante, Vivian Paley, Eliot Wigginton, Chris Zajac, and James Herndon create classrooms very different from one another (Herndon, 1968; Kidder, 1989; Mathews, 1988; Paley, 1979; Wigginton, 1985).

Yet even with these individual variations across classrooms within the same school, most teachers share beliefs about what they ought to do in their classrooms and what is best for students. These shared beliefs run like a bright red ribbon throughout a school tying together adults and children. So, cultures, organizational structures, and individual teacher beliefs matter in understanding how classroom practices have come to be as they are.

Now, I briefly turn to the present-day moment of science curricular reform to see where it fits into previous efforts to improve science content and pedagogy and its assumptions (both explicit and implicit) about the influence of district, school, and classroom organizations.

Science Curricular Reform In The 1990s

In *Science for All Americans* (AAAS, 1989), a document that guides Project 2061 and has influenced many contemporary science curricular reforms, the purpose of creating a science for living is vigorously and unapologetically stated. The current phrase for that purpose is "scientifically literate." Without reference to earlier efforts of progressive educators who shared a similar purpose, The American Association for the Advancement of Science (AAAS) endorsed a wholesale overhauling of the official, taught, learned, and tested curricula. The AAAS was less interested in constructing marginal changes in existing structures; they sought fundamental changes in what science content is taught, how it is taught, and what is learned and tested.

Other science efforts to create content and assessment standards are similarly motivated by a neoprogressive purpose of creating a science for living.

What has become obvious in the rhetoric and prescriptions for science education reform is that the official curriculum contains neoprogressive assumptions. However, in the desire to shift from age-graded to nongraded schooling and from teacher-centered activities to cooperative learning activities, what appears to be missing is an awareness of how powerful organizational influences have frustrated such changes in the past. The absence of serious attention in these documents to strategies in countering the powerful influences wielded by district, school, and classroom organizations and teacher beliefs suggests again that amnesia about earlier (and similar) reforms will simply create more rather than less complications in altering the taught and learned science curriculum (Gardner et al., 1990).[4]

Notes

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1. I focus on secondary school science because as I read the history of science curricular reforms over the last century, it is the concern over the high schools that dominates definitions of the problems, particularly preparing students for studying science in college. The impact of college admission standards upon secondary school curriculum has been noted fully and frequently. Solutions invariably focused upon subject matter taught in secondary schools. Nature study in elementary schools was aimed at an appreciation of nature and rural life; nature study never found a grip-hold upon secondary school science.

2. Note further that not all the sciences taught in secondary schools followed the pattern I described for the various decades. In physics, for example, the science for life purpose was a post-World War II phenomenon rather than occurring in the pre-World War II period as with other science subjects, according to Donahue (1993). "Unlike other subject areas that were altered by progressive notions of making education relevant to a variety of student interests and needs," Donahue writes, "physics was still most heavily influenced by the single goal of preparing students for college. In fact, most high school and college freshman physics classes used the same text." When "kitchen physics," and "everyday physics" texts were used in the 1950s and teachers' questions such as "What is the coefficient of friction between an automobile tire and the road?" were common, the motive often was to boost sagging enrollments in physics, a decline that had begun before World War II (Donahue, 1993).

3. For the description of institutional organizations where procedures and beliefs conform to social beliefs and are loosely linked to what happens in schools and classrooms, see Meyer & Rowan (1978) and Weick (1976).

4. In a fine collection of papers delivered at a 1988 conference of leading researchers deeply involved in science education reform, one of the 16 papers (12 pages out of a book of 339) deals with the social organization of the school and its consequences. None deal directly with the question of organizational influences on curriculum or instruction. Nor is there a listing for "organization" in the index (Gardner et al., 1990).

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Is Systemic Reform the Answer for Schools and Science Education? Cautions From the Field

"SYSTEMIC SCHOOL REFORM" has quickly become the preferred prescription for success in school reform (Smith & O'Day, 1991), including the reform of science teaching and learning (Ravitch, 1991). Whether, however, the systemic approach is "the one best strategy" for the restructuring of science teaching and learning is questioned in this article. We use the results of a qualitative study of five efforts to reform science teaching and learning[1] as a basis for introducing several "cautions" about the systemic approach. The specific purpose of these cautions is to promote a critical conversation about the systemic approach among those considering how best to reform science teaching and learning.[2]

First, we provide a brief discussion of what is typically meant by "systemic reform," drawn primarily from the work of Smith and O'Day (1991). Second, we describe a qualitative study of five science reform efforts, each of which represent different kinds of sites—a state education agency, an urban district, a suburban district, a small town/rural district, and a corporate sponsored multi-district effort. Third, we discuss the cautions about systemic reform that arise out of the study of each of these reform efforts. We end with a brief discussion of some alternative ideas about state-level efforts to reform science teaching and learning.

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What is Systemic Reform?

According to Smith and O'Day, the "fundamental barrier" to systemic reform "is the fragmented, complex, multi-layered educational policy system in which . . . [schools] are embedded" (p. 237). To overcome this "fundamental barrier" to successful school reform, Smith and O'Day propose a program of systemic reform consisting of "a unifying vision and goals (p. 246), a coherent system of instructional guidance (p. 247), and a restructured governance system" (p. 253) that is not fragmented. As Clune (1993) concludes, "The essence of systemic policy is to replace . . . [the current] fragmented nonsystem with a coherent system of curriculum controls at the level of national and state governments" (p. 244).

Referring back to Smith and O'Day's definition, the first aspect of systemic reform—"a unifying vision and goals"—is to be developed at the state level "to provide coherent direction and strategy for educational reform throughout the system" (1991, p. 246) with the "focus primarily on the core functions of the system; that is, on teaching and learning" (p. 246). The second aspect of systemic reform—"a coherent system of instructional guidance"—is also set at the state level, and its purpose is "to ensure that all students have the opportunity to acquire a core body of challenging and engaging knowledge, skills and problem solving capacities" (p. 247).

To achieve this, the state would develop, "curriculum frameworks which set out the best thinking in the field" (p. 247). While the frameworks "would

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set out desired intellectual curricular themes, topics and objectives in sufficiently long-range chunks, . . . [the frameworks would] not detail a day-to-day, week-to-week, or even a month-to-month curriculum for teachers to follow" (p. 247). These latter decisions would be made at the local level, although all choices would be made from an array of curricula within the state-developed framework. In addition, the state would fund the professional development of teachers for the implementation of the new frameworks and also would assess student outcomes using evaluation methods based on those frameworks.

The third aspect of systemic reform—"a restructured governance system"—attempts to address the fact that "much of the current literature on . . . restructuring . . . assumes that centralized policies regarding curriculum and instruction serve to undermine school personnel's sense of authority over their own program" (Smith & O'Day, 1991, p. 253). Although Smith and O'Day grant that providing autonomy to local schools has allowed a small number of individual sites to initiate successful restructuring programs, they argue that the lack of systemic coherency prevents the replication of such successful reforms on a widespread basis.

What is needed, according to them, is a coherent systemic strategy that "seeks to combine the vitality and creativity of bottom-up change at the school site with an enabling supportive structure at more centralized levels of the system" (p. 245). This "balanced" approach of bottom-up semi-autonomy and top-down guidance would, in their opinion, lead to successful, statewide school restructuring in which there would be significant improvement in student outcomes, including those in mathematics and science. Our research suggests, however, that this systemic approach to school reform may be neither so desirable nor so successful.

A Study of Five Reform Efforts

A qualitative research study was conducted as one part of a several-year effort to address administrative-oriented questions about reforming science teaching and learning.[1] Five different sites were selected that represented varied approaches to the reform of science teaching and learning. These sites included the state education agency (SEA), a large urban district, an upper-middle-class suburban district, a small town/rural district, and finally, a multiple-district reform effort initiated and coordinated by a major corporation.

At least two interviews, and sometimes five interviews, were conducted at each site during three distinct waves of interviewing over a 2-year period. The lead person responsible for coordinating the reform effort in each site was interviewed in order to develop a description of the reform process. Where relevant, a person who opposed the reform or who had a different perspective on the reform was interviewed to garner an opposing description of the reform process.

While a similar number of interviews were conducted at each site, this article focuses in greater depth on the SEA site because considerations related to this site raise key, framing issues of the article. Cautions are drawn more briefly from the other four sites. The focus of these cautions is directed, in general, toward a critique of the systemic approach to school reform and, in particular, to the reform of science teaching and learning.

Systemic Coherency Versus Messy Democracy

The SEA had recently begun planning for the development of statewide frameworks for the teaching and learning of science based on a "unifying vision" articulated by the new head of the SEA. This new framework was going to have "real teeth," according to a staff member. Not only would the congruency between the state frameworks and each district's science curriculum be determined by the SEA staff, but there would also be an assessment of student outcomes at three or four points during the 13 years of a student's public schooling. To emphasize the requirement for congruency, one SEA member said, "If their [a district's] curriculum doesn't fit . . . their charter [to operate as a school] gets jerked. They [then] can't give a diploma."

While the above quote indicates a top-down approach, the SEA staff said they knew that "top down does not fly"; instead, districts "need choices, informed choices." In striking a "balance" between top-down control at the state level and "informed choices" at the local level, the SEA appeared to be embracing a stance similar to that advocated by Smith and O'Day (1991). Indeed, an employee of the SEA in this study who had previously worked for a different SEA, one that had strong state-level control of the schools' curricula, noted that her current SEA

would not follow such a total-control approach; instead, she stated, "I think the model [followed in her current state] will have a lot of suggestions, a lot of outcomes and the questions and the styles and the assessment procedures will be written from the outcomes, but how you get there will be up to local control." In addition, as advocated by Smith and O'Day (1991), the SEA planned to draw its frameworks from the best national efforts, such as Project 2061.

What this state lacked, according to Smith and O'Day (1991), was support for teacher inservice programs. Because of budget priorities and cuts, there was currently little hope for any additional monies to be added to schools' teacher development budgets. The overwhelming majority of schools, thus, would have to provide or fund their own inservicing. However, the SEA staff would provide assistance to schools encountering difficulty in implementing the new frameworks. While the lack of funding for inservicing would certainly be a significant shortcoming, this SEA was, for the most part, implementing systemic reform as called for by Smith and O'Day (1991).

Our research at this site, however, raises some key questions about state educational policies and their relation to governance structures, questions that need further examination. These questions are directly connected to Smith and O'Day's central assumption:

> There is little purposeful coordination [between the multiple levels and responsible parties of our educational governance system]. . . . The policy generation machines at each level and within each level have independent timelines, political interests, multiple and changing special interest groups, and few incentives to spend time and energy to coordinate their efforts. As a result, policies compete, overlap and often conflict. [This] fragmented policy system creates, exacerbates, and prevents the solution of serious long term problems . . . that have become endemic to the system. (Smith & O'Day, 1991, p. 237)

Although this is a reasonably accurate description of the "policy system" in this country, this negative characterization of this system ignores the fact that the authors of the *U.S. Constitution* intended this division of power (this incoherency) to protect democracy and freedom. In other words, although Smith and O'Day probably did not intend this consequence, to agree with them is to implicitly call for a different kind of governance or policy system.

"Multiple levels," including the federal, state, district, and school levels, certainly exist within our "educational governance system." Moreover, each of these levels "have independent timelines, [different and often conflicting] political interests, [and] multiple and changing special interest groups." As we all know, both the federal and state levels are constitutionally subdivided into separate and multiple power centers—the legislative, the executive, and the judicial—for the purpose of "checks and balances." Even the district level has a legislative component (the board of education) and an executive component (the superintendent and other district staff). Additionally, each of these components is influenced by constantly shifting political, economic, social, religious, and racial interest groups, among others.

While some of these divisions of power are fundamental governance characteristics spelled out in the *U.S. Constitution*, other divisions of power, such as local school boards, are historical developments arising out of the same beliefs about dividing power that informed the construction of the federal *Constitution*. In other words, the division of power into these "multiple" levels and components is fundamental to the nature of representative democracy in this country.

To call, then, for coherency throughout "our complex, multi-level governance structure" is implicitly more radical than it has been characterized within the literature that advocates systemic reform. In fact, as Clune (1993, pg. 244) argues, "The bottom line is that a coherent system of educational governance in the United States would require a revolution in governmental structure." Advocacy, then, for systemic coherency is, in effect, advocacy for a different *Constitution*, a fundamentally different orientation toward governance.

Since such systemic coherency goes against fundamental ideas of governance in this country, and since incoherence, which Smith and O'Day (1991) claim is the present condition, undermines needed educational restructuring, a "middle-range" strategy of "loose" or moderate coherency might be more acceptable. While this "middle-range" strategy might avoid the radical questioning of the "multiple levels of our . . . educational governance system," discussed above, there would be additional problems.

Suppose, for example, the SEA were the focal point for developing the "middle-range" coherency,

as would probably be advocated by Smith and O'Day. In addition, suppose the SEA developed an approach in science teaching and learning that essentially paralleled the systemic reform approach. And, finally, because the SEA had previously learned that state-level edicts are ineffective (e.g., McLaughlin, 1991), suppose the SEA tried to bring enough players to the table to devise a policy that would receive widespread support. To do so, the state would need to garner support from a plethora of groups ranging from the interested federal parties to local parent and teacher organizations. To ensure even "middle-range" coherence and compliance at each level, the state could not afford to have the policy opposed by many of these groups or even by a few key groups.

At the very best, the resulting policy would most likely be a compromise possessing an appearance of unity but would, in fact, be a bundle of several contradictory orientations (Ball, 1990). Policies dependent upon support from many different groups (as most significant policies are), when examined in detail, are rarely coherent or unitary; instead, they usually combine many competing strands into a compromise of some sort. For example, the National Council of Teachers of Mathematics' *Standards*, a policy statement that calls for systemic reform of mathematics teaching and learning, is one such combination of competing or conflicting strands (Apple, 1992).

This view of policy was also supported in our study. One SEA informant noted that the staff spent "over 100 hours" deciding on the composition of the advisory committee because the selection process was all so "political." In addition, the SEA staff was quite aware of conflicts between the various science disciplines concerning an "integrated" thematic approach to science, as they believed was called for by such national science education reform efforts as Project 2061.

According to this informant, the conflicts arose because the groups' separate professional standings were "threatened": "OESTA wants to maintain earth science as a discipline. ACS wants to maintain chemistry. AAPT wants to maintain physics." Moreover, numerous other central or influential groups would also have some say in the construction of the new policy. The result, as we have argued, would not necessarily be an internally coherent policy but, rather, would be a unity of embedded differences and compromises. Simply put, internally coherent policies are rare (Rowe & Ball, 1992).

The resulting "unified" policy, however, is not the end of the process. Incoherencies (which also might be called local adaptations), which are endemic to multi-leveled democracy, will continue to erupt at all levels. Elections will occur, and a different party may take control and elect an SEA commissioner who seeks a different orientation or has different supporters in industry who want the policy rewritten for their benefit. The relative influence of various teacher organizations may shift, thus necessitating policy revisions. The state legislature, for various complicated reasons, may pass laws that contradict or undermine various aspects of the science education policy. Judicial decisions may similarly affect the policy.

In addition, as ample research has shown (e.g., Fullan, 1991; McLaughlin, 1991; Timor, 1989), individual districts and schools will creatively develop their own version of state policies, which may or may not be "coherent" with the original policy. All of this incoherency is but the normal and appropriate workings of democracy and the normal and appropriate adaptations of state policies to the contingencies of local situations. That some of these "workings" and "adaptations" may undermine coherency in science education reform is but the necessary cost of a multi-leveled democracy.

Consequently, the basic caution from the SEA site, in our opinion, is that a call for policy coherency runs counter to representative democracy as it is known and practiced in this country. Our "complex, multi-layered . . . policy system," which Smith and O'Day see as the primary barrier to school restructuring, is a fundamental characteristic of representative democracy, the goal of which is literally to divide power, as in the division of power built into the *Constitution*. The historical experience of those who wrote the *Constitution* was that undivided or "coherent" power, and the policies of such coherent power, led to egregious abuses. While the idea of coherent systems with coherent policies that are properly implemented throughout the system possesses a certain seductive appeal, in the end it is a dangerous idea.

Hierarchical Reform Does Not Work

The urban site illustrates the worst case scenario, but unfortunately it is not atypical of large, coherent bureaucracies. A group of educators drawn from throughout the district collaboratively developed a

new K-12 curriculum and then sent it for comment to all teachers of science in the district. The comments were collated, and changes were made based on these comments. The revised curriculum was subsequently given to all K-12 teachers of science for implementation. No extra inservicing was provided.

Our research indicated that the result of this approach to reform was that there was no system-wide commitment among the teachers to substantially alter their orientation toward science teaching. The teachers tended to view the reformed curriculum as simply another initiative from the bureaucracy to which they must adapt.

While this dismal picture seems to be an unlikely result of the systemic approach, as proposed by Smith and O'Day (1991), it may actually be a typical result. Although the systemic approach is an attempt to provide guidance at the top (the state level, in the case of systemic reform) and, at the same time, provide flexibility and freedom at the local level, the systemic approach is, nonetheless, a hierarchical, centralized, one-best-way approach.

Since a systemic approach depends on the positional power of the state within a hierarchy to allow it to mandate, monitor, and evaluate, a considerable distance develops between policymakers at the state level and the average teacher at the local level. Consequently, most teachers will know that, as usual, they are at the bottom of the policy hierarchy, recipients of that which they had no hand in creating but that which only they can make work. No matter how coherent a top-down policy is, those at the bottom—the science teachers—will know their location in the policy hierarchy and will act in accordance with this knowledge by adapting, ignoring, or merely obeying what they receive policy-wise, as they did within the urban site.

In fact, it could be argued, as is now being advocated in the private sector, that diffusions of innovation through coherent, hierarchic systems are not only unenthusiastically received at the production level, i.e., the classroom, but are financially more costly than decentralized innovation. Corporate systems such as IBM have found system-level guidance or frameworks do not provide the freedom, flexibility, and enthusiasm for a "local" division, such as the microcomputer division, to shape or adapt itself to succeed (make profits) in its particular environment.

The caution from the urban site, then, is that the systemic approach, regardless of how "balanced" it is between top-down guidance and local autonomy, may result in the same problems as have been experienced in the corporate sector and in many large hierarchic systems. When implemented throughout a large system encompassing hundreds of schools and thousands of teachers spread over many cultural, racial, and economic environments, systemic coherency will likely result in the development of a sense of distance and alienation between those enforcing the policy and those responsible for implementing the reform. Due to repeatedly experiencing negative consequences (low profits) from the use of hierarchic, systemic policy initiatives, the growing tendency in the private sector is to favor local initiative and control over systemic coherency and control. These private sector experiences, then, do not bode well for the systemic approach to school reform.

Successful Reforms Are Localized

In contrast to the urban site, the suburban site is, in many ways, the best case scenario. We would argue, however, that this best case scenario is unlikely to occur under systemic coherency conditions. This site's reform effort involved the high school earth sciences area only and, in contrast to the urban site, was restricted to only one school. The reform, thus, was done by a small group of people, all of whom were intimately involved in the project.

In our opinion, this group developed the best science education reform we have seen, and this judgment has subsequently been affirmed by the fact that they have received national recognition for their effort. This was science teaching and learning reform successfully accomplished in the way national leaders of such reform have been advocating. This group of reformers attained the ideal.

Much about this reform effort supports not the systemic approach but a more decentralized approach. First, according to several of the informants, the particular blend of individuals and a happy sequence of events were more responsible for the reform than any kind of planned, coherent approach. Several informants said if one of several individuals had not been at the right place at the right time, the reform would never have occurred.

Second, the leadership of the effort, in opposition to what a systemic coherency approach would advocate, was not hierarchical. In fact, different people led at different phases of the process, depending

upon each person's skills. But this shift among the various leaders was not planned; "it just happened." While the systemic approach could not be said to require the same leadership at all phases at the local level, the top-down, hierarchical approach to leadership tends to lead in that direction.

Third, and probably most important, some of the key leadership in this reform consciously saw the reform as anti-hierarchical. In fact, the reformers actually set up structures to protect their local reform from the hierarchic systemic coherency of the district. For example, an advisory board was established not just to provide advice but also to protect the reform from those with more formal or hierarchical power in the educational system. One key person even argued that the reform would have been lost or substantially watered down without the protection of the advisory board.

The basic caution raised by this site's reform is whether a systemic approach would enable or facilitate what happened with this group of reformers on a statewide basis. The idiosyncrasy of the reform, the shifting, collaborative nature of the reform leadership, and the anti-hierarchical inclinations of the reformers should, at least, raise doubts about whether the systemic approach would result in the blooming of "a hundred flowers" like this one. Instead, as Clune (1993) has concluded, and the private sector is increasingly concluding, the systemic approach may actually undermine the possibility of such fruitful blossoms.

Everyone Has to Be Involved

The small town/rural site reform could be characterized as the "middle way" approach between that of the large bureaucracy of the urban site and that of the small immediacy of the suburban site. On one hand, teachers from within the district developed a reform of which most national experts in science education would approve. On the other hand, only a portion of those required to implement the reforms were involved in its development. Interestingly, this "middle way" actually led to more problems than either in the large, hierarchical urban district reform or in the small, anti-hierarchical suburban district reform.

There is little doubt the teachers involved in developing the reform did excellent work. Not surprisingly, those who were involved in the reform effort or who were in previous agreement with the reform's initiatives usually professed strong support for the reforms. Those who were not involved in the process or those who were not predisposed to the new, hands-on approach, however, stated they did not like or even opposed the reform. The result, therefore, was a split among the district's elementary teachers who taught science. The key problem was that the development of the reform involved only some of the teachers.

Again, we would suggest this site, especially as contrasted with the urban and the suburban sites, offers another caution against the systemic approach. The fundamental question that arises in comparing the three sites is whether a vision and framework for reform developed at the top of a system can be satisfactorily implemented at the bottom of the system. The answer, in our opinion, is no. The best reform, the one at the suburban site, developed its own vision and strongly depended on the enthusiasm and idiosyncratic peculiarities of a small, independent, even, anti-hierarchical group. The reform with the least real change at the classroom level, the effort at the urban site, is typical of large, coherent systems. The reform with the most problematic consequences, that of the rural/small town site, indicates that all teachers implementing a reform need to be involved in the process.

Thus, the evidence from the three district sites indicates that, first, systemic reforms tend not to work and that, second, everyone implementing the reform needs to be engaged in developing it (which cannot occur within the systemic approach). But both of these conclusions are just two aspects of the same lesson: Successful reforms are developed locally by all of those who implement the reform, not by those higher up within the system.

We conclude, therefore, that successful reforms are not typically developed systemically. This conclusion, however, is anything but new with this study. Both McLaughlin (1990) and Fullan (1991) have said that one of the most salient conclusions about education reform is that it cannot be created top-down. In addition, Clune (1993, p. 242) emphasizes that the local school site should be "the locus of curriculum reform because [it] is the place with a definable student population and a distinctive staff capable of adopting, adapting, and implementing goals."

While I would imagine that Smith and O'Day (1991) will contend that they are taking such research

and commentary into account, we would argue they are trying to have their cake (maintain the hierarchy with ultimate power at the top) and eat it too (get the district to carry out the reform as if it was district's or school's own creation). This study, like the conclusions of McLaughlin, Fullan, and Clune, should cause advocates of the systemic approach some concern for the efficacy of their approach.

Breaking Systemic Boundaries

The corporate initiated, multi-district site's reform provides an additional caution against the systemic approach. In fact, that a reform is being initiated from this site undermines the very idea of a coherent educational system.

A large national corporation—whose business is heavily dependent on science, that hires many scientists, and that believes support for its business would be improved with an increase in general scientific literacy—held a conference about science teaching and learning with the districts in the area surrounding its corporate headquarters. From that conference, and in consultation with teachers, the corporation decided to initiate a multi-district effort to improve science teaching and learning at the elementary level. At the time of this study, this effort was only in the early stages, but a committee composed of district-level representatives, usually the superintendents themselves, from each district had been developed.

According to some informants, the real purpose of this committee was to get the superintendents to support the way in which the corporation and some elementary science teachers thought science teaching and learning needed to change at the elementary level. Thus, the corporation, in collusion with reform-minded elementary teachers, were developing an environment that would subsequently support science education reform.

The systemic approach, however, requires not only that reform must be framed and controlled at the top but must be conducted only within its own boundaries. A center of reform activity located outside the system, hence not under the direct control of the system, undermines the coherency of the systemic approach. It is as if the reform of one division of a corporation were being initiated and controlled from outside the boundaries of the central office of that corporation. The caution, then, of this reform effort is not about the particular approach they are taking to reform. The lesson of this site is that a reform effort may be initiated and controlled from outside the educational system, a possibility that might be eliminated by a coherent system.

The Cautions Recapitulated

The caution from the SEA is twofold. First, policies, developed in representative democracies, are bundles of contradictions and compromises, and thus they are not coherent or unitary. Second, the multi-leveled governance of education, of which Smith and O'Day (1991) are so critical, are key aspects of our version of representative democracy. Indeed, systemic reform approaches similar to those of Smith and O'Day have a distinct air of repugnance for the necessary messiness of democracy.

The caution from the urban site is that coherent, rational, hierarchical systems tend not to produce successful reforms. The caution from the suburban site is that the best reforms may be locally originated, locally controlled reforms. In other words, successful reform is local, contingent, and idiosyncratic, not systemic and hierarchic. The caution from the rural/small town site is that half a loaf is worse than none at all. Reforms require the local engagement of all participants, not some participants.

Finally, the caution from the corporate/multi-district site is that school reforms may emerge and be guided from outside the "system" and, thus, not be systemic. Clearly, all of these cautions challenge the systemic approach and suggest investigation of a different, more decentralized approach to science education reform.

A Different Approach

This article suggests some cautions that need to be considered by those who support the systemic approach or who are considering implementing a systemic approach. It also suggests that there may be other useful ways to approach the reform of science teaching and learning. We conclude, then, with some thoughts about how a state education agency might approach such reform on a different basis than systemic coherency.

First, the SEA could recognize there are always going to be multiple centers of power and multi-levels of power in initiation, development, implementation, and maintenance of an education policy. Even large bureaucratic organizations and systems, including

corporate ones, are only partially hierarchical; there are virtually always multiple centers of shifting power, influence, and resources.

Second, leadership may arise anywhere, short-term or long-term. In fact, the idea of leadership itself is relatively hierarchical. Real reforms may be dependent on multiple roles, only some of which are typically identified as leadership, but more than one of which may be necessary. For example, one person in the reform effort may not fulfill a traditional leadership role, but her or his ability to facilitate the interactions of the group may be necessary to the success of the reform. In such a case, a reconceptualization of leadership might be needed.

Third, the best reforms tend to be intimate affairs, involving, as Dewey (quoted in Sarason, 1982) suggested, everyone directly connected to the reform. Leaving people out creates conflict and more need for control. In a certain sense, it could even be argued that efforts to hierarchically develop coherency actually results in less coherency and more failure.

Fourth, we do not need hierarchical systems to diffuse successful reform or innovation. There are alternative ways to facilitate local reform efforts independent of hierarchical power. State agencies, but one among many possible centers, could facilitate such diffusion without needing to control it, as could other centers, including universities, corporations, and local school districts (Clune, 1993). Fifth, a wide range of possible outcomes could be used to determine success, and outcomes could be used to refashion the reform rather than to punish.

We are not sure any of these five propositions would guarantee success; we are only suggesting we might want to explore other possibilities besides the systemic approach. We might want to think about how an SEA could facilitate reform of science teaching and learning without relying on a systemic approach.

For example, the SEA could recognize that, in the reform of science teaching and learning, there already are sites involved in various approaches to such reform. Rather than trying to impose its system on these already developing sites, the SEA could recognize and support those quality reforms, even if the resulting approaches to science education reform are widely different. The SEA's goal, then, could be quality reforms rather than only one type of reform.

To promote a range of quality reforms, the SEA could sponsor a conference highlighting quality efforts and use the reformers themselves to show others how they did it. The conference could also include researchers discussing the typical characteristics of successful reforms, such as the involvement of everyone who must implement the reform. The SEA could fund release time for those involved in quality reforms to assist other districts in developing their own reforms. Unsuccessful schools and districts could be provided assistance from SEA staff, successful reformers, and university staff.

The point is not that these specific suggestions are the best approach, but that the SEA could devise many different ways to promote successful reforms of science teaching and learning, leaving the entire reform, from vision to implementation and maintenance, in the hands of those who must implement it. The point also is that the systemic approach is certainly not the only approach or, in our opinion, the best one. Given the cautions raised here, a thorough, critical discussion is needed regarding both the systemic approach and alternative, non-systemic approaches to science education reform.

Notes

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2. While the study of rational systems is not the focus of this article, it should be noted there exists a large body of work that is highly critical of the type of rational systems model assumed by the systemic approach critiqued here (see, for example, Zey-Ferrell, 1981). For the most part, contemporary organizational theory would suggest systemic reform, as it has been characterized, is a dubious idea. Although this article only partially addresses these system-model issues, the critique of rational models widely supported within contemporary organizational theory does inform the perspective from which this article is written.

3. The state, districts, schools, and informants in this study will remain anonymous. Changes have been made in the characterization of the institutions and informants to increase their anonymity.

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Who Systematizes the Systematizers? Policy and Practice Interactions in a Case of State-Level Systemic Reform

WHAT EXPERIENCES IN SCIENCE do U.S. high schools offer, how and by whom are they determined, and what do the experiences signify, both for the teachers and students who encounter them most directly and for the wider polity whose resources support them? We have surprisingly inadequate answers to these questions about science curriculum, policy, and their relationship, even though they may be critical to the success of the systemic initiatives now absorbing large portions of federal, state, and local resources (Clune, 1993; Cohen, 1990).

Paradox in Science Curriculum

Consider a persistent but poorly explained paradox in science education: Adult elites attribute high status and power to science, but the discipline fails to command much allegiance from the culture's recruits. American youth flood out of the school science "pipeline" in what some deem crisis proportions, they score poorly on international comparisons of achievement, and, as scientific illiterates, they are named a threat to the nation's economy and defense and to a democratic polity.

Why don't youth take to this valued form of knowledge? A common response diagnoses school curriculum as the culprit; at the same time, properly restructured, curriculum is also prescribed as the cure. As promised in proposals from the experts (American Association for the Advancement of Science, 1989; National Science Teachers Association, 1988), if science lessons are made excellent (e.g., "integrated," "relevant," "constructivist") and if they are distributed equitably to all students, "American youth will be first in the world in science and mathematics achievement" by the year 2000 (U.S. Department of Education, 1991, p. 3).

However commonsensical, this diagnosis and treatment may be deluded, if not deceptive. We say this, not to defend the science that schools teach or to discount the possibility of change, but to assert the inadequacy of prevailing theory about curriculum and its practical import for research, practice, and policy. Specifically, when we posit curriculum as a stable, causal variable that can be readily and rationally manipulated to benefit individuals and the polity, we overestimate its impact because we underestimate its complexity.

Practically, for example, the standard view has undergirded initiatives since World War II that have provided relatively extraordinary infusions of resources to improve the quality, and more recently, the equity, of science curriculum. However, while some aspects of curriculum improved in some locales for some time, today's lessons remain just about as mindless, unengaging, and differentially distributed as yesterday's (compare Bruner, 1960; Conant, 1959; Stake & Easley, 1978; Tobin & Gallagher, 1987).

Similarly, the standard view neglects how people encounter school science and how they understand

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it. For instance, we have "virtually no research . . . that places student experience [of curriculum] at the center of attention" (Erickson & Schultz, 1992, p. 467), nor any that ventures to explicate the perspective that state policymakers bring to science education (Cohen, personal communication, May 1994). Instead, most research proceeds on the assumption that studying science is a good thing.

Hardly less troubling is the more recent proposition that school science is political (e.g., Harding, 1991; Shymansky & Kyle, 1992). While it prompts acknowledgment that there is conflict over the science that schools teach, the insight is then trivialized with pleas for consensus in the interests of efficiency (e.g., Champagne, Lovitts, & Calinger, 1989) or portrayed as an indelible concomitant of race, gender, and/or social class (Oakes, 1990). Because neither of these popular characterizations of curriculum politics can account for the other, just as neither attends to the particular circumstances in which one or the other may in fact obtain, they fuel rather than forestall today's polarized, whatever-works brand of politicking.

Finally, rather than considering the institutional and social contexts that impinge on school science, the prevailing model of curriculum ignores or controls for them. We plan fine curricula, assuming they are a function of good ideas about science—"structure of the disciplines," "constructivism"—but our plans neglect the high school's overweening emphasis on order, differences between school communities, and general social conditions, any of which may be more important for change than rational argumentation. At the same time, we remain hamstrung by persistently variable or ambiguous results because we lack the data that might provide some clarification. For instance, information about circumstances might let us sort out when science teachers find it sensible to act as professional planners of curriculum (Tobin, Kahle, & Fraser, 1990) and when, as efficient technicians, they implement the designs of experts (Smith & O'Day, 1990).

In their extensive review of science education, White and Tishler (1986, p. 893) also note the paucity of useful studies of school science, explaining that "science educators [and, we would add, policy scholars] have not found curriculum research an attractive activity . . . because it is complex." It entails understanding interactive, often tacit, sociocultural as well as scholastic processes of teaching and learning; the formal, but also the informal, procedures of curriculum planning that operate across local, state, and federal levels; the organization of schooling and its complicated, often oblique, relationship to other social institutions such as the family or the economy; and the central yet increasingly contested role of scientific knowledge in the history, culture, and politics of the United States.

Curriculum research is not only "daunting," according to White and Tishler, but the studies we have are of limited scope and utility. Designed to tackle "small parts of the complex set," they yield some insights, but "greater possibilities of understanding lie in more comprehensive studies" (p. 893).

An Alternative Stance

Seeking those "greater possibilities of understanding," we began in 1993-94 an ethnographic and historical study of curriculum practice, policy, and their relationship. We seek to describe and analyze the politics of representing school science (LaTour & Woolgar, 1986; Marcus & Clifford, 1986) by studying empirically the science that schools teach, and how, in what circumstances, and with what private and public consequences diverse constituencies in and around public schools struggle to define it. Thus, we are interested in two domains:

1. The first domain has to do with the *diverse definitions of school science* that participants in and around public high schools espouse and negotiate, as they seek to have their view legitimated as school science. We compare a variety of characterizations of science, including those constructed by teachers and students in traditional and innovative ("integrated") science classes; by members of school cultures, such as administrators, support staff, and faculty in and out of science; by community members such as "science boosters" and parents, particularly the middle- and upper-middle-class parents to whom schools purportedly cater but whose influence has been assumed, not specified; and by designated experts such as district personnel, scientists, and state policymakers.
2. The second domain relates to the *formal and informal linking mechanisms* that connect idiosyncratic definitions of science developed in local discourse communities such as science classrooms and faculty cultures. These linking mechanisms also connect the scholastic constructions of science with more stable, if largely inexplicit, sociocultural precepts of membership and differentiation, such as gender, intellectual ability, or social class. Formal mechanisms may include budgetary

resources or high-stakes testing; informal mechanisms may include teachers' or students' expectations about studying science.

We report here one phase of our larger study. We take as a specific case the state-level, systemic initiative, *Science Framework for California Public Schools* (California Department of Education, 1990), and its enactment in two "ordinary" school communities in southern California. Because of its direction and scope, the *Framework* is widely heralded as both progressive and ambitious. Its programmatic recommendations mirror those proposed by such prestigious science foundations as the National Science Teachers Association and the American Association for the Advancement of Science. Policy scholars regularly cite the *Framework* as a model for the nation and, because of California's size and centralized review process, its decisions do influence education markets.

Unlike most of the earlier policy reforms of the 1980s, which focused on raising standards or professionalizing teaching and which assumed such restructuring would trickle down to change classrooms, the new *Framework* targets the classroom itself. It not only credits classrooms as the heart of schooling but it also recognizes that, traditionally, they have been the hardest sites to change. Thus, it both invites schools' participation and builds in "levers" to ensure their compliance. For instance, whether a school adheres to *Framework* recommendations or not, it must participate in the annual, statewide test (CCTP, formerly CLAS)[1] and its score on the test is reported in local newspapers.

Integrated Science

"Integrated science" is one component with which the *Framework* seeks to leverage a major redefinition of science curriculum and to reorient fundamentally how teachers and students engage with it and with each other. Accordingly, the California State Department of Education recommends that high schools abandon the "layer-cake curriculum" in which students move, year by year, through the separate disciplines of science. This curriculum is deemed outmoded and, inadvertently or otherwise, as limiting many students' access to science. Instead, schools should provide all students interdisciplinary courses in which the various sciences are brought together to relate to important, everyday themes such as energy or the universe.

We focused on this innovation because, despite its promise, we also expected it would ground crucial battles over school science. First, its emphasis on "interdisciplinary," "relevant," "hands-on" science for all challenges traditional curricular interests. Historically, for example, high schools have distributed "practical" knowledge to less-advantaged children, while more-advantaged children work on "academics" (Kliebard, 1986; Labaree, 1988). Second, the reform appears when some citizens, including groups of women, minorities, fundamentalists, and environmentalists, contest increasingly the worth of science and public education (Douglas & Wildavsky, 1983; Gross & Levitt, 1994; Harding, 1991).

The Research Project

Battles did erupt during the year we spent in two administratively-similar high schools that were the locus for our study. Part of one of California's largest school districts, the schools are typical of many public, U.S. high schools: large (about 1,800 students), urban but not inner city, and offering the traditional, tracked curriculum (Goodlad, 1983). They had also begun to implement *Framework* recommendations. Both piloted Integrated Science 1 in 1993-94, are using it to replace ninth-grade biology and general science courses (e.g., physical science, human body) in 1994-95, and project replacing tenth-grade chemistry with Integrated Science 2 in 1995-96. Further, the two schools differ in their curricular reputations and the socioeconomic status and ethnicity of their student bodies, so we could also compare the interaction between curricular and cultural differentiation.

We proceeded like anthropologists studying exotic cultures or historians studying strange times, because we regard local, contemporary settings as equally arbitrary. Accordingly, we treat present-day, U.S. classrooms or high schools or policy arenas as local "worlds" of science, with characteristic habits of mind, behaviors, and meaning systems (Bernstein, 1983; Fish, 1980). People socially construct these worlds, including their places within them and their affiliation with other worlds, by using symbols and other resources to which they have varying degrees of access. Participants' words are important symbolic resources, not Truth about reality or epiphenomena that merely embellish reality; they are public artifacts that people use to do things (Lemke, 1989).

Because we conceptualize both curriculum policy and practice as *symbolic action* (Burke, 1966; Edelman, 1977; Geertz, 1973, 1983; Goffman, 1967; Kliebard, 1990; Meyer, 1986), we attend to what people do with words and to the mostly tacit cultural knowledge that their words point toward, which makes what they do sensible rather than simply blamable or praiseworthy (Spindler, 1982). Our principal concern is to describe what school science *is* by elucidating what it *means*, rather than the more usual "what works," because we assume that people act reasonably (if not always rightly) given their understanding of their situations (Erickson, 1986). If students say lessons about evolution are "brainwashing," even if they exaggerate, their characterization is intrinsic to what biology is; it will modulate the significance we can attach to such hard facts as enrollment tallies or test scores.

We used an interpretive research methodology (Erickson, 1986), assuming that by living in and around the two schools through a school year we might grasp the academic and social knowledge that characterize local "worlds" of science there and, by comparison, others' different worlds, including our own. Working principally in traditional and "integrated" science classrooms but also in corridors and communities, we used several research strategies to gather data, including participant-observation, interviews, document collection, and audiotaping lessons.

We have begun the process of analyzing the data. We report here some preliminary observations that bear on curriculum theory and its import for research, practice, and policy. We propose that present reform efforts are right in their claim that curriculum is systemic, but wrong in their characterization of the system. Life in science classrooms is indeed connected to the events and ethos of surrounding schools, communities, and policy arenas. However, the connections may not be as direct, unidirectional, rational, or readily manipulable as the systems analogy suggests. Data gathered during this case study suggest a reorientation that places curriculum policy and practice on the same plane. Accordingly, we must study curriculum policymaking with the same cultural and political questions that we study practice, asking who makes policy and how, rather than taking as subjects for inquiry only policy goals, implementation, or effects. Further, in studying curriculum practice, we must ask not only whether and how it corresponds to policy, but how practice informs and acts back on policy.

Holding Science at Bay in the Classroom

We began observations in science classes, ready to see the social construction of "high-status knowledge" (Oakes, 1990). However, we now harbor doubts not only about its high status; we wonder in what sense science is being taught at all. Unlike policy initiatives that target the versions of science that schools offer, our inquiry probes whether science is what teachers and students in science classes are up to.

Our question arose when we encountered an unanticipated curricular pattern across almost all of the science classes in the two schools. During the first weeks of the school year, school science seemed to be unabashed social control (parents must sign contracts that explain teachers' rules and expectations; lab reports must have 1" margins; no pencils in labs). Then, science seemed to be math (significant figures; how to use the exponent function on calculators; scientific notation). After that, science became vocabulary and basic skills (names of lab equipment; the periodic table; families and phyla); later, it was holidays (homecoming, Thanksgiving, Christmas); and, near semester's end, it was little but tests (local exams, advanced placement and international baccalaureate tests, Golden State Exam, minimum competency tests, CLAS).

Perplexed by the general pattern in which teachers and students seemed to be holding science at bay, we sought more concrete manifestations. We noticed, for example, that during units on evolution, teachers insisted on the "scientific" basis of the theory but apologized repeatedly for it, while students maintained a noticeable silence. In follow-up interviews, students said that they disagreed seriously with teachers' views; some characterized the unit as "brainwashing." In their interviews, teachers noted that state and district guidelines stipulate that they must teach about evolution, but they must also observe certain cautions in what they say and ask students to do.

Another, less-charged example occurred in labs. During labs, all but one or two students did everything they could *not* to act scientifically: They were offhand rather than precise in taking measurements; they studiously ignored rather than observed the phenomena. In further analysis, we hope to specify these

observations by showing how teachers and students construct the *absence* of school science in their talk together during lessons and by delineating the particular situations of classroom, school, and community within which they find such a construction sensible.

A Dramaturgy of Compliance

Our observations also included the first-year implementation of "integrated science," confirming some critics' questions about this key feature of the *Framework*. Equity and excellence in school science served as watchwords, or slogans, in what we came to call a dramaturgy of compliance (Goffman, 1967).

Thus, in classrooms, Integrated Science 1 developed haphazardly, as an incoherent amalgam of bits and pieces of the physical, chemical, and biological sciences; the disciplines the teachers were accustomed to teaching received the most emphasis. "Hands-on," "practical," "lab-based" science was trivial; teacher talk, textbooks, and worksheets prevailed, accompanied by student hijinx. Curriculum was neither "innovative," "interdisciplinary," nor "coordinated," but represented what one teacher aptly described as "on-the-fly" selections from resources already developed for traditional, discipline-based courses. In short, "integrated science" had the content and form usually attributed to lower-track classes.[3]

This result is not surprising, given that the district allocated almost no resources to support the translation of the curriculum-on-paper into the actual units and lessons that constitute any curriculum-in-practice. At best, each school provided the teachers who were piloting Integrated Science 1 with three or four release days to develop the year-long course. Yet, in a strange twist on "less is more" (Sizer, 1985), participants, including teachers, did not protest the lack of resources for curriculum development. Instead, displaying a "maddening air of simple wisdom" (Geertz, 1983, p. 85), they maintained that a revolutionary, "world class" science curriculum would be generated, even with such depleted resources that some classrooms in these "ordinary" schools do not have enough desks for all the students, all are decidedly grimy, and the annual, per-pupil instructional budget is under $50, just about the price of one new textbook.

Most district resources were targeted at higher administrative levels, not classrooms. Thus, in 1991-92, the district brought together a "science team" of various personnel to consider how the district would implement the recommendations of the newly-amended *Science Framework*. The next year, it gathered the science department chairpersons from the five high schools to produce a district-wide guide for "integrated science." During 1993-94, as Integrated Science 1 was being piloted, several inservice programs brought all high school science teachers together, although the day-long meetings did not focus consistently on the curriculum reform.

Meanwhile, local school politics bubbled along behind stage to produce an all-too-predictable scenario. Meetings of the high school chairpersons fractured, with several of the chairs withdrawing from planning the district course of study because others did not appreciate their areas of expertise. Teachers panned the district guide as "useless," perhaps because they had no input or because it was too generic. As the district proceeded with plans to expand the sections of Integrated Science 1 so that in 1994-95 all ninth graders would take it instead of biology or general science, principals were mustered to "make" teachers adhere to the integrated science course of study.

However, the district no sooner announced the proposed switchover than parental resistance erupted; some biology teachers went public with their reservations too. By late July 1994, the district had backtracked: In 1994-95, ninth graders would be able to choose their science assignments. However, this arrangement might further stratify the schools if informed parents request that their children continue with biology, especially since Integrated Science 1 is not yet approved as meeting the University of California's entrance requirements.

State-Level Testing Scandal

The local comedies of errors played out against a larger backdrop of a state-level scandal for schools. In March 1994, the California Learning Assessment System (CLAS), the linchpin binding practice to policy, began to come undone. CLAS is billed as an innovative, "authentic" assessment. Different from the individualized format and abstract, multiple-choice items found on traditional standardized achievement tests, CLAS asks students to work together to develop responses to open-ended, practical problems, such as discussing the moral implications of a short story or performing a lab experiment and hypothesizing

its environmental implications. Its items are aligned with *Framework* recommendations for active learning, thematic teaching, and hands-on, real-life curriculum.

The CLAS scandal began when scores from the first round of tests, given in 1992-93, showed California's students at all grades to be below, often far below, the performance average set for reading, writing, and mathematics (science testing began in 1993-94). The scores also exposed the "open secret" that schools are not equal (Metz, 1986): The best scores in the Los Angeles region were obtained by schools in Beverly Hills, Palos Verdes, and the West Side while the worst scores came from the Los Angeles Unified School District, particularly from South-Central Los Angeles. According to area newspapers, inquiries about private school admissions skyrocketed.

Next came charges of censorship. According to some, the California State Department of Education (SDOE) withdrew test items (e.g., an excerpt from Alice Walker's short story, "Rose Lily") after several right-wing, religious groups objected to their "anti-religious" content. SDOE said there was no censorship; the items were withdrawn because they had been leaked and published in newspapers and, therefore, they could no longer be valid measures of unrehearsed learning. Not content to leave well enough alone, SDOE added that the test was not available for public inspection for the same reason. When this created a stir, SDOE changed its tune and claimed the test must be kept secret so that copyright is protected.

Needless to say, challenges to the test escalated. They were based not only on objectionable content or secrecy, but also on the open-ended format that critics (again, from the right) said risked personal invasiveness. Several school boards ruled to refuse to give the test. Again unprepared, SDOE countered that the test is compulsory and hurried to consult its lawyers. Meanwhile, the judge adjudicating suits ruled that he would have to be given a copy of the test and that schools would honor parental requests to excuse their children from the tests.

Then, an even more dramatic turn of events occurred. As *The Los Angeles Times* reported in April 1994 (and as confirmed in August 1994 by an investigatory commission chaired by Lee Cronbach), the scoring of the tests was utterly invalid (Wilgoren & O'Reilly, 1994). Not every test was scored; not even half of all the tests in every district were scored, as SDOE had promised; in some districts, the school score reported in the newspapers was based on as few as five tests; in others, tests that were scored came disproportionately from members of various ethnic minority groups. SDOE explained the shortcuts by pointing to legislative pressures for results. Regardless, the fact remains that children, schools, and citizens suffered public censure for poor performance but the performance was manufactured by the education profession. If this is systemic reform, who is systematizing the systematizers?

Perhaps the scandal explains the absence of public debate about the value of more testing for California's already often-tested school children, or about the use to which CLAS will be put. For example, the test is supposed to produce accountability. But, will learning that the Los Angeles schools score below those of Beverly Hills change the educational hierarchy, or will it simply let schools jockey for position in a system in which, by definition, almost all will not be the winner? The scandal may also explain the silence of liberals and educational professionals in the face of challenges from the religious right about the validity of performance-based tests. Still, whose interests *are* served when most schools in the state fail to measure up, especially when evidence suggests that many "functioning" adults would not meet present standards?

In any event, Governor Wilson deleted the test from his proposed budget until SDOE can assure him its house is in order. SDOE has also taken action: It changed the name of the test. CLAS is now the less memorable CCTP (California Comprehensive Testing Program).

Conclusion

These data concerning curriculum practice and policy, set within a cultural frame, suggest some of the inadequacy of prevailing curriculum theory, including its current "systemic" manifestations such as the *Framework*. Moreover, the data document that the prevailing theory is not limited to top-down reforms, but can also infuse bottom-up initiatives. At whatever level, however, the prevailing theory limits the questions we ask and the practices we propose. Relying on it, we cannot accommodate the persistent dilemmas and proliferating contexts of school science, even though they are crucial considerations if we are to do science curriculum and its politics differently (Sarason, 1982).

As an alternative, we have presented policy and practice as symbolic action, placing them together on the same plane so that we can see their "systemic" relationship somewhat differently. In both, for example, the social construction of meaning is central. In both, meaning is patterned but not readily predictable; in neither is it an unequivocal given, an aggregate of individuals' "schema," or an attribute determined by bureaucratic sector or race, class, or gender. Rather than pigeon-holing perspectives or averaging out their differences, this theoretical orientation directs without providing formulae. With it, we scrutinize what people do with words to consider how and when they use symbolic resources to define "worlds," recruit others to join, and coalesce with others to take responsibility for curricular proposals (Kliebard, 1995).

Attention to political language (Edelman, 1977) can also help us understand how the standard view of curriculum persists, despite its problems. Fundamentally, the standard model succeeds symbolically, even if it fails pragmatically (Kliebard, 1990), by employing a characteristically American doublespeak that promises something for everyone, no matter how paradoxical (Kammen, 1972; Varenne, 1983). Because "America," like all cultures, maintains itself by hiding its basic premises, we rarely note the chronic ambiguity in practice and policy as an artifact to be explained, but instead, we minimize it as a methodological anomaly or an administrative insufficiency (e.g., loose coupling). Thus, systemic initiatives promise both "high-status" science *and* universal distribution, top-down standards *and* site-based management, subject matter competence *and* constructivist process, or democratic decision making *and* professional expertise.

With such ambiguous goals, programs mobilize broad support. However, they also hand schools an impossible agenda. If change proves elusive once again, then schools—once again—will serve as scapegoats for ills that society is unwilling, and possibly, unable, to tackle (Commager, 1975). Then, however ironically, the chief effect of current systemic reforms will be to feed the growing cynicism about science and schools.

Again, alternatively, curriculum can be viewed as a *translation* of culture, not culture's mechanical transmission or its miraculous transformation. It provides local, consequential *versions* of culturally-valued academic and social knowledge. Rather than stipulate state guidelines, the face-to-face exchanges in classrooms, textbooks, or other forms as *the* curriculum (e.g., Johnson, 1977) or simply list them all (Gehrke, Knapp, & Sirotnik, 1992; Good & Brophy, 1987), we pose curriculum as "piled-up structures of signification" (Geertz, 1973, p. 7). With this orientation we may explicate both local "strata" and the larger precepts—the web—that tie together local versions of scholastic and sociocultural knowledge.

Studying both policy and practice empirically, as symbolic action, produces a record of the variability and ambiguity of school science and raises questions about the relationship between policy and practice. Most often, we ask whether practice matches policy, and we study formal mechanisms such as CLAS whose design specifically connects local classrooms and state mandates. However, the mostly symbolic rather than instrumental success of policy and practice suggests that informal, cultural linkages also deserve attention. Therefore, we seek to understand the language of education (Jackson, 1968), including science education, reasoning that people use it to spin the webs of meaning—cultures, or here, worlds of science—in which they are "suspended" (Geertz, 1973, p. 5, paraphrasing Weber).

While language's sacred forms, represented in policies, commission reports, textbooks, or curriculum research, deserve attention, equally important if less often examined is the commonsensical vernacular spoken in and around schools. Like popular novels (Fischer, 1987), the mundane discourse in classrooms and schools does not simply reflect what we take to be familiar about school science: It *makes* the familiar. That is, ordinary talk may formalize and make noticeable social currents that are already set in motion but not yet realized.

Thus, even though scholars, including policy scholars, find it easy to dismiss the seemingly undisciplined, cliché-ridden language of classrooms, we might learn from it. Our queries should not be about whether practice matches policy, but about how practice produces the taken-for-granted. Such knowledge about what *is* in school science remains prerequisite to thinking and acting differently toward what school science might be.

Notes

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1. California's CAP test (California Assessment Program) was redesigned and renamed CLAS (California Learning Assessment System) in 1993; the new acronym was dropped in 1994, following the scandal we outline in the section, "State-Level Testing Scandal," and was replaced with the less memorable, CCTP (California Comprehensive Testing Program).

2. Students in Integrated Science 1 during 1993-94 were originally scheduled to take biology or general science.

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Robert Donmoyer

The Rhetoric and Reality of Systemic Reform: A Critique of the Proposed National Science Education Standards

In November 1994, The National Research Council (NRC)[1] distributed a draft of the *National Science Education Standards* for comment and critique. With the release of this draft, we have an opportunity not only to review the proposed *National Science Education Standards;* we also can begin to see how rhetoric about systemic reform will get played out in reality. The concept of systemic reform, after all, helped inspire and guide the development of the *National Science Education Standards*. The concept also has been endorsed by a number of other influential organizations interested in science education reform and educational reform more generally (e.g., The Business Roundtable, 1992; National Governors Association, 1991), and it has undergirded other major reform initiatives such as the National Science Foundation's (NSF) state, urban, and rural systemic initiatives and the American Association for the Advancement of Science's (AAAS) Project 2061.

Here I briefly review the central ideas associated with the notion of systemic reform and indicate how these ideas are manifested in the draft of the *National Science Education Standards*. I then critique the draft of the *National Science Education Standards* and consider what this critique suggests about the viability and utility of the notion of systemic reform.

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What is Systemic Reform?

Systemic reform, according to Smith[2] and O'Day (1991), is an attempt to replace the current "fragmented policy system," which has "little purposeful coordination" across educational policy initiatives and reform, "with a coherent system of curriculum controls at the level of national and state governments" (p. 244). The key word here is *coherent*. Fuhrman and Massell (1992), in a document that further develops Smith and O'Day's notion of systemic reform, state that "some use the term [simply] to refer to comprehensive change that is focused on many aspects of the system, [while] others stress the notion of policy integration, coordination or coherence around a set of clear outcomes" (p. 2). They go on to note that

> the political system is more accustomed to the "comprehensive" notion. Typically, legislatures build coalitions by bundling together many discrete programs. With omnibus or comprehensive approaches, many policymakers can share credit and satisfy diverse constituencies. More integrated approaches require tradeoffs and difficult choices among policy options. (p. 4)

Despite these tradeoffs and difficult choices, however, Fuhrman and Massell make it clear that they—and Smith and O'Day—endorse the integration/coordination/coherence meaning of systemic reform. They write: "The past failures of fragmented policy suggest that 'integration' is critical to reform that is truly 'systemic'" (p. 4).

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So, how does this integration occur? How does one go about building Smith and O'Day's "coherent system of curriculum controls?" Smith and O'Day indicate that we must first develop "a unifying vision and goals" (p. 244). Then all other aspects of the system—e.g., preservice and inservice teacher education, tests and assessments, governance structures—must be reoriented toward accomplishing the agreed-upon goals and making the vision a reality.

One final point before proceeding: In addition to advocating "increasing coherence in the system through centralized coordination" (p. 254), Smith and O'Day also endorse—and incorporate into their notion of systemic reform—"increasing professional discretion at the school site" (p. 254).

How can Smith and O'Day embrace these two apparently contradictory ideas? They do it by distinguishing between means and ends. They give discretion for the former to the micro level and responsibility for determining the latter to macro-level decision makers. "While schools have the ultimate responsibility to educate thoughtful, competent, and responsible citizens," Smith and O'Day write, "the state—representing the public—has the responsibility to define what thoughtful, competent and responsible citizen will mean in the coming decade and century" (p. 254). What do we get by parceling out responsibility in this way? According to Smith and O'Day, we "combine the vitality and creativity of bottom-up change at the school site with an enabling supportive structure at more centralized levels of the system" (p. 245).

Systemic Reform and the National Standards

Systemic reform advocates' influence is readily apparent in the November 1994 draft of the *National Science Education Standards*. In the draft's introduction, for instance, we are told that the standards "provide a *vision* of learning and teaching science" and that they "provide assistance in making decisions and policies that will bring *coordination, consistency,* and *coherence* to the improvement of science education" (NRC, 1994, p. I-3, emphasis added).

As in the literature on systemic reform, talk of coordination, consistency, and coherence is quickly balanced by acknowledgments of the need for discretion and flexibility at the local level: "A hallmark of American education," the authors of the *National Science Education Standards* announce near the beginning of the document, "is local control, where boards of education and teachers make decisions about what their students will learn" (p. I-3). To further reassure advocates of local control, we are told that national standards simply

> present criteria by which judgments can be made by state and local school personnel and communities. They are based on a vision, and they address a range of characteristics of school science *so people can decide* which curriculum, staff development activity, or assessment is appropriate. National standards *provide assistance* in making decisions and policies that will bring coordination, consistency, and coherence to the improvement of science education. (NRC, 1994, p. I-3, emphasis added)

Although the NRC astutely avoids using Smith and O'Day's (1991) straightforward talk of a "system of curriculum controls at the level of national and state governments" (p. 244), such a system is implicit in the NRC's talk of coordination, consistency, and coherence. Also, like Smith and O'Day (1991), the NRC uses the distinction between means and ends to smooth over the apparent contradictions in its rhetoric. "The standards describe outcomes," the NRC tells us,

> not the rate or manner in which students will achieve them . . . . Decisions about programs and the means to accommodate the different rates of learning are left to curriculum developers, state and local school systems, and science teachers. (NRC, 1994, p. I-7)

The authors of the draft also use Smith's means-ends distinction to endorse "students learning science by actively engaging in inquiries of interest and importance to them" (NRC, 1994, p. I-5), on the one hand, and statewide curriculum frameworks (which articulate predetermined outcomes) and statewide assessment systems (which determine whether curriculum framework developers' predetermined outcomes have, indeed, been met) on the other.

There is a potential problem here: It is normally much easier to distinguish between means and ends at the level of rhetoric than it is in reality. Political scientist, Charles Lindblom (1968), in fact, observed long ago that we do not really know what our values are until we are forced to make hard choices about means, i.e., until we must decide how to spend limited financial resources or how to use precious commodities such as teacher and student time. For Lindblom, therefore, the conceptual distinction between means and ends is, in essence, meaningless, because when we talk of ends without reference to hard choices

about specific means, our talk is vague, and, consequently, trade-offs and hard choices are obscured.

Vagueness as Political Strategy

Vagueness, in fact, is a favorite tactic of politicians intent on building a winning coalition. It is a strategy they use to forge agreements when agreement does not exist, and a method they employ to make adversaries allies (at least temporarily).

Vagueness, in other words, is one of the poles that holds up the politician's "big tent." If the politicians' big tent is big enough (i.e., if their rhetoric is vague enough), all sorts of people with all sorts of differing and even contradictory views can be accommodated. The differences and contradictions, of course, are not really resolved; they are simply temporarily obscured. Eventually those who implement the legislation that has been passed or those who must enact the mandate that has been endorsed at the polls must confront the tradeoffs vagueness obscures and, in the process of making hard choices about means, they will also, in effect, finally decide which ends get endorsed and supported.

The vagueness strategy is very much in evidence in the NRC's draft document. The content standards in this draft, for instance, are even more vague than the content standards that appeared in earlier drafts sent out for review. Consider, for instance, the content standards that define what students should know and be able to do with respect to the topic of scientific inquiry. There are three inquiry-oriented standards, one each for grades K-4, 5-8, and 9-12. The standards are so vague that the exact same wording is used at each level: "Students will develop abilities necessary to do scientific inquiry [and gain] understanding about scientific inquiry" (NRC, 1994, p. V-19).

Less process-oriented content standards exhibit the same sort of vagueness. Consider, for example, the following content standard for science and technology at the middle grade level:

> Content Standard E—5-8: As a result of activities in grades 5-8, all students should develop
> • Abilities of technological design
> • Understanding about science and technology
> (NRC, 1994, p. V-91)

Readers desiring more specificity are simply referred to Project 2061's (1993) *Benchmarks for Science Literacy*. This document is also more than a little vague on some key points (Donmoyer, 1995), but it does offer rather extensive lists of relatively concrete (by comparison to the NRC's content standards, at least) outcomes that students are expected to have achieved by particular grade levels. Taxpayers might legitimately ask why so much time and effort, not to mention so many federal dollars, needed to be invested in articulating national content standards, if the content standards produced are so vague and the developers of those standards simply refer readers to more specific standards already developed by another group. The NRC's relative vagueness, however, serves a useful political purpose. A brief anecdote demonstrates why this is so.

Several years ago, I showed a draft of Project 2061's *Benchmarks for Science Literacy* to a well-known educational reformer. He was appalled, and with great rhetorical flourish, he announced: "Jim Rutherford [Project 2061's director], you've lost your way." The reformer went on to explain that he feared that teachers and curriculum developers who based their work on *Benchmarks for Science Literacy* would become so concerned with curriculum coverage—so involved with insuring that students had completed the many benchmarks Project 2061 had articulated—that there would be no time to engage in the student initiated, problem oriented, somewhat improvisational form of teaching he—and also Project 2061 (see Chapter 13 of *Science for All Americans*, Rutherford & Ahlgren, 1990)—had endorsed. He said his fears would certainly become reality if Project 2061's benchmarks were translated into high-stakes tests, and he cited, as support for his argument, a historical precedent in which high-stakes tests drove curriculum and teaching in traditional directions despite rhetoric to the contrary.

I doubt that this reformer will have a similar reaction to the draft of the *National Science Education Standards*. Indeed, the relative vagueness of this document serves the NRC well in terms of garnering political support. The NRC, in fact, has been able to bring under one big tent a number of quite different educational philosophies, philosophies that in the past were thought to conflict (see, for example, Eisner & Vallance, 1974).

The NRC's "Big Tent"

For instance, accountability-minded folks, including those who believe education is largely a process of learning the content of the academic disciplines,[1] will

be pleased by the more-or-less traditional, discipline-based organization of the content standards and the promise that these standards will be made more specific in state-level curriculum frameworks. Similarly, those who believe predefined content and skills can and should be measured at various points along the way[4] will be happy to know that content standards will be operationalized in state-wide assessment systems. At the same time, for less hard-headed, more romantic souls who believe that education should be more of a student-centered quest for personal meaning[5] and a largely student initiated process of inquiry,[6] and who, consequently, assume that teaching must be more of a serendipitous, reactive, and responsive process than a preplanned and proactive one, the standards document provides a series of charming vignettes about what classroom life will look like after the standards have been enacted.

In one vignette, for instance, an elementary school teacher spontaneously fashions a series of lessons to teach content standards related to both scientific inquiry and the physical properties of matter from a student's observation that the water in the watering can used to water classroom plants had disappeared over the weekend. When no student admits to drinking or spilling the water, the teacher asks what happened to it. One student hypothesizes that Willie, the pet hamster, must be getting out of his cage at night and drinking the water. The students decide to test this hypothesis by covering the watering can so Willie will not be able to drink the water. When no more water disappears, the students conclude that Willie was, indeed, the culprit.

At this point, the teacher once again intrudes and asks how they can be sure the hamster did it. The students concoct an ingenious plan: They place the hamster's cage in the middle of the sand table each night, smooth the sand, and check the following morning for footprints.

After a bit more of this sort of experimentation, the students become convinced that their ideas about Willie are, indeed, wrong, and the teacher takes advantage of this teachable moment to suggest some experiments to help her students observe and better understand the phenomenon of evaporation. Even, at this point, the teacher remains attentive to what students do and say. A student's comment about her mother's use of a dryer to dry clothes and her observation that the clothes take longer to dry when her mother does not turn the dial to heat, generates a new round of experimentation to determine whether water does, indeed, disappear faster when it is warmer.

Somewhere, John Dewey must be looking down and smiling. But, given the national standards' emphasis on the mastery of predetermined content and the need to measure whether mastery has, indeed, occurred, E.L. Thorndike and B.F. Skinner must also be pleased (or at least appeased). The NRC has indeed constructed a big tent under which those who normally disagree can gather. Like traditional politicians who support both subsidies for tobacco farmers and programs to persuade citizens to stop smoking, the NRC has built a powerful coalition by constructing a vision of reform that promises something for virtually everyone.

A Likely Retort

At this point, the NRC's defenders can be expected to object: The NRC's big tent is fundamentally different from the big tents constructed by politicians; while politicians' big tents are built on vagueness and obfuscation, the NRC's big tent is grounded in a creative synthesis, they will argue; this synthesis *legitimately* accommodates what were previously thought to be antithetical points of view.

Exhibit A in support of this argument will almost certainly be the draft document's support of authentic assessment. When we operationalize this concept—and the draft document does provide some rather concrete examples of how this might be done—it appears as if we can indeed legitimately accommodate rival points of view. We can, for instance, satisfy those with accountability concerns yet still accommodate those disciples of John Dewey who nod with approval when they read the draft document's disappearing water vignette, which was summarized above.

This latter group, after all, never quarreled with assessment per se; their quarrel was with the inauthentic character of standardized tests and the tendency for these tests to lead to inauthentic teaching and learning. When we make assessment authentic, so the argument goes, we will be able to use the potent tool of assessment to drive curriculum and teaching in a very different direction, in fact, the direction Dewey's disciples would like to see them head. Thus, advocates of accountability and advocates of more student-centered teaching and learning can legitimately come together under the big tent the NRC has created.

The problem here is that the *National Science Education Standards* related to assessment not only endorse authenticity, they also endorse traditional validity and reliability criteria. This latter endorsement, in turn, implies support for a rather high degree of standardization, and there is at least some face validity to the charge that standardizing authenticity is an oxymoron. The untimely demise of California's efforts at statewide performance assessment (Page, this issue) and the disastrous experience with performance assessment in science education in Great Britain (Black, 1993) provide empirical support for this point of view. Once again, it appears as if it may be easier to give something to everyone rhetorically than it is in reality.

Conclusion

The NRC's "unifying vision" does not provide a foundation for a new form of educational decision making, one in which inevitable tradeoffs and difficult choices are confronted and resolved. Rather the national standards the NRC has drafted are, themselves, products of the very sort of bargaining and "big tent" comprehensive politics systemic reform advocates criticize. Consequently, the unifying vision the NRC has articulated actually obscures the tradeoffs and difficult choices that eventually will have to be made.

Furthermore, the difficulty is not so much with the way the NRC has implemented the systemic reform concept; the fundamental problem is with the concept itself. Smith and O'Day's (1991) neat and tidy means-ends distinction, which works so well in the realm of rhetoric—including rhetoric about systemic reform—gets messy when we move from rhetoric to reality. We must realize, therefore, that in reality we may not be able to have it all and that tradeoffs will have to be confronted and hard choices made even after a "unifying vision" has been created. At the very least, we should openly acknowledge the task we have delegated to curriculum developers, test makers, and especially teachers, and we should not be surprised nor should we blame them when they fail to do the impossible.

Notes

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1. The National Research Council is the principal operating agency for the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. Working within general policies established by these organizations, the National Research Council provides services to the government, the public, and the scientific and engineering communities. The federal government charged the National Research Council with developing national standards in the area of science and funded the development effort.
2. Marshall Smith is the former dean of Stanford University's School of Education and currently serves as under secretary in the United States Department of Education.
3. Eisner and Vallance (1974) label this an academic rationalist conception of curriculum.
4. Eisner and Vallance (1974) label this a curriculum-as-technology view.
5. Eisner and Vallance (1974) label this a self-actualization conception of curriculum.
6. This is a cognitive processing orientation, in Eisner and Vallance's (1974) conceptual scheme of "conflicting conceptions of curriculum."

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Lauren A. Sosniak

Inviting Adolescents Into Academic Communities: An Alternative Perspective on Systemic Reform

THE CONTEMPORARY CONVERSATION about educational reform centers almost exclusively on K-12 school organization and classroom instruction. However, the development of academic knowledge, skills, and dispositions probably cannot and certainly should not depend solely on work done in elementary and secondary schools. The value of certain non-school experiences is demonstrated in a summer program at the University of California at Berkeley, the Academic Talent Development Program (ATDP).[1] As a program that aims to supplement, not supplant, school experiences, ATDP begins to reveal the potential and importance of "the relation of various educative interactions and institutions to one another and to the society at large" (Cremin, 1976, p. 24).

To say that schools are not sufficient as institutions for the development of scientific talent is not to suggest any necessary shortcomings of these institutions. It is only to recognize the place of schools in the lives of American youth. A recent estimate indicates that youth who attend classes every day they are expected to do so, through the age of 18, would have spent 9 percent of their lives in school (U.S. Department of Education, n.d.).

Even if schools were enormously successful in the tasks they set for themselves, and the tasks others set for them, the "risk and opportunity in the non-school hours" (Carnegie Corporation, 1992) are far too substantial to leave unaccounted for and unaccountable. By telling the story of ATDP, a story about inviting adolescents into academic communities and about trying to make the development of academic talent accessible to ever larger portions of American youth, I hope to make a compelling argument for "a less school-centric vocabulary [that] will enrich the public policy options available to us" (Lagemann, 1993, p. 681).

The ATDP Program

Each summer, ATDP serves several hundred students from the San Francisco Bay area. For six weeks, youth between the ages of 11 and 17 attend classes, do homework, go on field trips, and work for credits. Teachers plan lessons, attend faculty meetings, scavenge for space and materials, and create and grade student assignments. Classes are offered within five ATDP "departments": natural sciences, computer sciences, mathematics, social sciences, and humanities. Classes are held on the campus of the University of California at Berkeley, two or more days each week, with the number of hours of class time determined by the nature of each course.

On the surface, ATDP looks and sounds a lot like "school." But the people responsible for the program do not think of themselves as in the business of running a school, and my own observations, based on spending the summer of 1993 as the proverbial "fly on the wall" of the program (Sosniak, 1994), suggest that ATDP is, indeed, something very different

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from school. ATDP is an opportunity for students to learn about, take part in, and form a commitment to academic communities. It is an occasion for youth to join ongoing conversations of the sort that educational reforms claim are both important and too frequently missing in school contexts.

The program is guided by a vision of setting out for students academic and intellectual possibilities they might choose for themselves, and helping students successfully negotiate those choices. It is guided by a vision of welcoming a wide range of youth into a common community of scholarship and into subcommunities of the different disciplines and fields of study. The policies and practices of the program are not only consistent with this vision but are renewed by continuing reference to this vision, as illustrated in the following:

- Courses are offered within subject-specific departments. Careful attention is paid to developing courses that emphasize enrichment opportunities and that encourage deep engagement with subject matter and with people who share a passion for the subject matter.
- Students are allowed to take only one course each summer. Students make their choice from a program book that describes each course thoughtfully. Each course description is written by the teacher who will be responsible for the course, and aims at creating a vision of what is possible and desirable for the summer experience.
- Faculty are chosen for their commitment to the substance and pedagogy of their subjects and to working with adolescents who might be, or might become, similarly committed. ATDP teachers are faculty and graduate students from the University of California at Berkeley, middle-school and high-school teachers, and members of the local community.
- Pedagogies across the program emphasize small group and cooperative work, and experiences "in the field" with masters of the subject matter. These themes are central to the work within each course, to the conversations that take place at weekly teacher meetings, and to a variety of practical decisions made by program administrators.
- Students are admitted to the program not solely nor even principally on the basis of standardized tests but, rather, on the basis of a serious commitment to a particular course of study for 6 weeks. The application demands attention from students and their parents. It calls for work in simply applying to the program, and the application process highlights the work involved in taking part in the program.
- The program has multiple built-in practices that emphasize keeping in contact with students, encouraging contact among students, and building community through the active participation of students in program-wide experiences. Some of these are described later in this article.
- Students' continuing participation in the program over a period of years does not require outstanding grades in program courses but, rather, requires demonstrated commitment to engaging seriously with subject matter and with others similarly interested in the subject matter.

The Students

During the summer of 1993, 848 students enrolled in ATDP. Fewer than half were students new to the program; more were returning for a second or even a third summer.

As might be expected, many of the students who take part in this program are from well-educated and economically secure families, and have demonstrated strong academic ability in traditional ways (standardized test scores, school grades). However, because of the unusual criteria for accepting students into the program, and because of strong outreach efforts on the part of the program director and staff, the program serves an unusually diverse population.

The ATDP population is ethnically and linguistically diverse. Approximately one-third of the students served over the past 4 years have been Caucasian; the majority of the students represent the various ethnicities distributed throughout the San Francisco Bay area. Fifty-eight percent of the population served identifies English as the first language learned; the list of the first languages represented by the rest of the student population numbers around 52.

The ATDP population is surprisingly academically diverse for a program of its sort. More than 19 percent of the students who have enrolled have standardized reading achievement scores that place them below the 80th percentile on those tests. School grade-point averages range from 2.0 to 4.0.

The families of the ATDP student population are diverse also in their economic status and educational attainment. Family incomes are distributed across a range from less than $20,000 to well over

$100,000. Parents' education also is broadly distributed, with a significant population having, at most, a high school diploma or its equivalent and a significant population having earned graduate degrees.

The program serves a diverse student population in part because the communities with access to the Berkeley campus are diverse. However, the student population also reflects the serious outreach efforts made by program staff. ATDP has built strong collaborative relations with a nearby large urban school district and with a rural and largely Hispanic school district from "the valley." These relations, and determined fundraising efforts for minority student participation, have allowed significant numbers of students who might not have thought about attending ATDP on their own, or who might not have been allowed to attend ATDP if scores on standardized tests were a central criterion for admission, to join the community of adolescent scholars. The continued interest of the students who join the program because of outreach efforts (they return to the program for multiple summers in even higher percentages than "walk-in" students) suggests that the ATDP staff is correct in its assumption that the development of academic talent is possible and desirable for a larger population than we have historically assumed.

A Learning Community

ATDP is an intense program, for both students and faculty. Some ATDP courses "cover," in 6 weeks, the curriculum for advanced placement high school courses. All ATDP courses place serious demands on students, in and out of class. In a relatively short amount of time, students work intensely, with serious subject matter, and demonstrate visible academic accomplishments. They write computer programs, poetry, and short stories. They put on plays, translate Latin, and learn to converse in Russian and Japanese. They learn to speak the languages and tell the stories of biologists, archaeologists, and chemists.

Coursework places heavy emphasis on communities learning with and from each other. Students are strongly encouraged to work together in and out of class. Class lists with everyone's home phone number, including the teacher's, are distributed on the first day of the program. Some assignments for each course require cooperative work. Teachers make multiple, explicit references to the value of working together, building a community of scholars.

Community is defined and redefined in several ways. Students form a course community with a teacher. They also are introduced to members of a larger community of adults sharing their substantive interests. Students visit laboratories on the Berkeley campus, and Berkeley scientists visit ATDP classes. Classes take trips to commercial and government science laboratories such as Genentech and Lawrence Livermore Lab. The marine biology group collects samples with marine researchers; the archeology group visits a working archeological dig. Local poets are invited to poetry class to give readings. A dance choreographer for *A Winter's Tale* agrees to teach one of the dances to a Shakespeare group. The work of academic talent development is intense and intensely social.

Community is not limited to groups of people working together in a single classroom, or people with common substantive interests; it includes the larger group of adolescents taking part in the summer program. Although ATDP classes are scattered across the Berkeley campus, the program builds visible networks across classes and departments. The ATDP staff (with help from students) produces a weekly, four-page, professional program newsletter. This newsletter includes information from across the program, information from outside the program that might be of interest to this academic population, activities for students, and contributions by students. During the summer of 1993, the newsletter included: a discussion of changing admissions requirements for the University of California; a scavenger hunt taking place over several weeks, calling on students to get to know ATDP participants and the Berkeley campus, and offering a prize to the class collecting the most items; and a series of reports by former students and current mentor-tutors on their experiences with some of America's most selective colleges.

ATDP also creates organized study groups for certain courses and provides mentor-tutor arrangements for individual students and groups. And there is always someone in a program office to talk to about experiences in the program and plans for the future.

The ATDP office in Tolman Hall serves as a physical and spiritual center for the program and the students. The office is open to all, and program participants and their parents stop by at all hours every day. Students and teachers use the office as a place

to hang out, or to meet before taking off for other sites and activities. They come to report highlights of their experiences or to offer a helping hand (calling to check on student absences, for example, or preparing program materials). Students and parents come looking for additional ways of joining the ATDP community, and the ATDP staff members always are accommodating.

The program is both the individual courses students pursue and the affiliation with a community of scholars (young and old). The program is a learning community not only for the students but also for the teachers and staff.

Each year, a small number of teachers new to the program join a larger group of returning teachers. The returning teachers assume considerable responsibility for helping the new teachers acclimate to the program. There is much talk among teachers—at two pre-program meetings, during weekly staff meetings, and, less formally, in the Tolman office early in the morning and at the end of the day. Voluminous written program information is shared with, and partially prepared by, the teachers (including a large three-ring binder for each course, with forms for lesson plans, student evaluations, and homework referrals). There are regular classroom visits among the faculty. New teachers are welcomed into small and large circles of teachers who shape the program as much as they are shaped by it.

Finally, community is not limited to program participants and alumni. During the regular school year, students with experience in ATDP invite others to become members of the community. They bring their friends, show them how to fill out the application, advocate on their behalf with program staff making admissions decisions, and talk with the program director about getting their friends into a "good" class. This is particularly the case for students who themselves have been welcomed into the community through outreach efforts. ATDP teachers recruit colleagues similarly, if less aggressively.

What seems most important about the socialization of students, teachers, and each with the other, is that it is planned and respectful. The idea of a learning community is not an incidental outcome of the program, rather it is one of the aims that guides program policy and practice. Greene (1989) argues that "people are more likely to . . . choose or to adopt standards if they see themselves as members of a community marked by certain commitments and always in the process of renewing itself" (p. 11). Commitments to academic subject matter, to working together to examine serious ideas, and to joining and building communities of like-minded scholars, are visible in words and deeds in classrooms, teacher meetings, and casual conversation in and around the office.

The Fit Between Program and Context

ATDP is not a program that exists by chance or happenstance, nor a program that runs by inertia. It is guided by a strong director with an animating vision, a vision of education sufficiently inspiring to give new life to an activity. Her animating vision awakens possibilities and stirs action. It offers guidelines for judging some policies and practices as more appropriate than others. The ATDP vision is partly moral and partly pedagogical.

The director believes each of us has a moral imperative to promote the development of academic talent. This obligation is not limited to people in "schools"; rather, it is the duty of the range of societal institutions and organizations that are themselves dependent on the academic inclinations of our society. She believes further that we are particularly obliged to promote the development of academic talent for students sometimes thought of as educationally underrepresented or underprepared. In other words, students who may have the fewest academic resources available to draw on at home or in school become the special purchase of those of us with the greatest academic means.

The director's pedagogical vision assumes that academic talent is not the province of a limited few but, rather, is a possibility for a wide range of America's youth. In her vision, the central pedagogical problem is not a matter of identifying the handful of students who, according to some scientific measure, have special "potential" for academic talent, and then providing educative opportunities to such students. Rather, the central problem is a matter of finding ways to welcome all who might be interested into enthusiastic, disciplined, academic communities. In her vision, also, welcoming students into academic communities is not work that can take place solely in classrooms; it requires that students have opportunities to see the work of those communities outside of school, in people's lives.

The director's pedagogical vision also assumes that academic talent is subject specific. The aim of ATDP is to welcome students into communities defining themselves by particular substantive interests: biologists, chemists, mathematicians, computer scientists, writers, specialists in literature. There are no subject-independent courses (e.g., "leadership," or "creative thinking") offered through ATDP. Students choose subjects of interest and then work with adults and other students sharing the same interest. Over a period of years, students have the opportunity to work persistently at a single subject interest or to experiment with participation in a different subject community each summer.

Many educators may well have animating visions that never find their way into practice. In part this is undoubtedly a matter of the initiative and skill of the visionary. In part, however, this may be a matter of a misfit between the vision and the context for its implementation. The director of ATDP has been fortunate that her vision is reasonably consistent with the needs of the institution within which she works, and she has been given considerable time and freedom to develop her ideas.

The University of California at Berkeley is dependent on the academic inclinations of society and is obliged for its own survival to promote the development of academic talent for students sometimes thought of as educationally underrepresented and underprepared. Berkeley, like all of America's best universities, depends on a reasonably large pool of students enthusiastic about serious academic development. And Berkeley has available during the summer some of the very resources that would support a program like ATDP: a few classrooms not otherwise used by university summer school classes, and graduate students and faculty looking for ways to spend a few summer weeks productively.

ATDP fits well within the general mission of the university. Its talent development focus, with careful attention to subject matter of importance to academic communities, and its efforts at outreach to underrepresented communities, serve public relations functions as well. ATDP serves the community; ATDP also prepares students for and recruits students into undergraduate programs at Berkeley. Finally, because ATDP is self-supporting, there is no drain on university financial resources.[2]

ATDP has had the good fortune to develop at its own pace and in its own image. In the absence of having to prove itself immediately, to the institution within which it is situated or to any funding agency, it has been possible for the director to experiment and to do so without having to cater to fads or anyone else's pet interests. The director and her staff have worked together over a half dozen years, tinkering continually. While many, perhaps all, of the staff and faculty of ATDP regularly read professional literature and keep in touch with emerging educational ideas, their work with ATDP is neither dependent on nor necessarily linked to anyone else's vision.

Education and Schooling

ATDP is an educational program, not a school program. The habit we have of speaking about education and schooling as if they were the same, or almost so, is an unfortunate one. It dramatically limits the analyses that might be conducted and the possibilities for policy and practice that might be considered (Boyd, 1993; Lagemann, 1993). It denies the educative opportunities that might arise, or might be inhibited, during the bulk of students' lives.

Cremin (1971) has argued elegantly for acknowledging the diversity of curricula being taught by countless organizations and institutions, and for holding these groups to "the same careful scrutiny from the standpoint of education" (p. 220) as we typically hold our schools. Tyler (1977), in his analysis of needed changes to his classic 1949 volume, *Basic Principles of Curriculum and Instruction*, pointed to the same dilemma: his and our inability to think about schools and the school curriculum as situated within larger and equally important curricular contexts. Well-informed as these appeals were, they have been largely ignored by educational research, policy, and practice (Jackson, 1992).

ATDP is one of many organizations and institutions outside of K-12 schooling with an academic curriculum. The focus of this program is related to but broader than the students' experiences in school. The program acts purposefully to define for youth a range of academic communities they might join, to welcome youth into working instances of such communities, to teach youth the rules and standards of the communities, and to support youth in adopting as their own the standards of a scholarly life in the sciences, mathematics, or the humanities. ATDP is an out-of-school opportunity that attempts to reveal the possibilities and the richness of serious investment

in academic subject matter. ATDP is self-conscious about helping youth see academic knowledge and skills as much more than merely "school" work.

The ATDP approach to the development of academic talent is consistent with growing bodies of research on the development of talent (Bloom, 1985; Sloane, 1991; Sosniak, 1987, 1990) and on learning that takes place outside of school (see, for example, Boyd, 1993; Lave, 1988; Resnick, 1987; Rogoff & Lave, 1984; Saxe, 1990). Both bodies of literature call serious attention to the significance of opportunities in the non-school hours for unusual learning successes. Findings from work on the development of talent highlight the importance of understanding the lives people lead, the situations they encounter, the models they have for development, and the communities available to them for support, inspiration, and sustenance. Those who became unusually accomplished adults had, as youth, a pervasiveness of opportunities to learn, and resources for learning, outside the school—at home, with neighbors and peers, and through institutions and organizations loosely linked if at all to kindergarten-through-university schooling.

Studies of learning outside of school highlight similarly the multiple and social contexts for education. The messages students receive about what is worth knowing and doing come from many sources, some complementary and others apparently at odds with one another. The success of students in developing academic talents depends at least in part on the social contexts available to them for learning "that," learning "how," and learning to care about something of importance to others and of importance to their own lives.

Whether or not we pay careful attention to the experiences students have in the 90 percent of their lives spent outside of school, those experiences have a powerful impact on the accomplishments of youth over the long term. Under these circumstances, it behooves educational policymakers to take seriously educational experiences writ large, rather than focusing almost entirely on experiences that take place in elementary and secondary schools.

Ironically, a program such as ATDP appears to be something of a misfit with the contemporary government view of talent development and the parallel movement at the moment toward systemic education reform. The recently released government report making "A Case for Developing America's Talent" (U.S. Department of Education, 1993) focuses attention almost exclusively on schools—as both the problem and the solution for the development of talent. The current push toward systemic education reform also is almost entirely school-focused, and appears to maximize consistency across educational arenas at the expense of the animating visions and individual initiative of educators such as those responsible for ATDP.

If contemporary research revealing the power of social contexts for learning is taken seriously, a single-minded focus on school reform—systemic or otherwise—can no longer be considered sufficient. Educational reformers need to think broadly about education rather than narrowly about schooling. We need to begin asking what policies would prompt various institutions and organizations to think about their own responsibilities in inviting and welcoming American youth into the adult communities we value.

Nowhere would a focus on education, rather than schooling, seem more important than for youth typically thought of as educationally underrepresented or underprepared. As Rose (1989) writes:

> To live your early life on the streets of South L.A.—or Homewood or Spanish Harlem or Chicago's South Side or any one of hundreds of other depressed communities—and to journey up through the top levels of the American educational system will call for support and guidance at many, many points along the way. You'll need people to guide you into conversations that seem foreign and threatening. You'll need models, lots of them, to show you how to get at what you don't know. You'll need people to help you center yourself in your own developing ideas. You'll need people to watch out for you. (pp. 47-48)

Some of these people may be teachers, principals, or guidance counselors. Some may be neighbors, business people who take an interest in youth, citizens willing to tutor and mentor, or even you or me. Each of us who knows a language (of statistics, literature, genetics, social science, cybernetics, Japanese) has the power to welcome youth into important conversations. We may do so individually, erratically, or sporadically; or our society might begin to experiment with ways of doing so as a part of public policy.

ATDP points to the existence of important possibilities for students, and raises questions about what educational reform is doing to ensure that all youth are likely to have opportunities out of school that

support and enhance the development of their intellectual knowledge, skills, and dispositions. ATDP is just a single example of a much larger phenomenon that needs to be examined and developed: multiple institutions in relation with each other providing educative and engaging academic opportunities for American youth.

We need not be constrained in our thinking about multiple contexts for academic education by examples of activities that take place in school settings, or activities that take place during the summer. We need not be constrained by ideas about large programs, serving several hundred students each year. Museums and firehouses, hospitals and libraries, big businesses and small, all could be invited to think about the contributions they could be making to the development of talent; each could be invited to propose its own situation-appropriate opportunities welcoming students into the communities of people who make such institutions and organizations their life work.

We can continue to look for educational reform focusing principally in our schools. Or we could consider the life experience of our youth and begin to hold a much larger part of society responsible for the scientific, cultural, and intellectual development that will be the mark of our society in the next century. My preference, obviously, is that educational policy be constructed to ensure that multiple opportunities for academic development are available to all youth, and that a significant portion of such opportunities are mutually enhancing and socially inviting. I developed this orientation watching the richness of youth and adult life in the Academic Talent Development Program at the University of California at Berkeley during the summer of 1993. The question my experience has left me with is whether others will choose to see this aim as a necessary part of "systemic" reform.

Notes

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1. ATDP is three programs, really. The Older Student Program (OSP) is the focus of this report. The Younger Student Program (YSP) is run by the same administrative staff, but operates classes of different sorts, at a different location. "Explorations" is a program of one-day activities, scheduled for Wednesdays during the ATDP summer session. These activities are available as enrichment options to students in either of the 6-week programs as well as to people not involved at all in either of the longer programs.

ATDP also is a program with a 12-year history, only a portion of which is represented in this article. Some years ago ATDP was a "satellite" program for the Center for Talented Youth. In recent years, the program has made dramatic shifts from that orientation—shifts in intentions, policies, and practices. In the process, ATDP has become a quite different example of educational possibility and opportunity. Thus, the program has itself been involved in "restructuring," and, in turn, offers insights into the rethinking of educational possibilities for students and teachers alike. This article represents ATDP in its current constellation only, speaking to the past 4 or 5 years of its operation, under the direction of Nina Hersch Gabelko.

2. Tuition and fees during the summer of 1993 ranged from $320 to $705, depending on the nature of the course; only one course cost more than $550. Twenty-two percent of the 1993 ATDP students received financial aid.

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The Learning Environment as a Site of Science Education Reform

CONTEMPORARY DISCUSSIONS of school reform target many candidates as sites for change. For example, in this issue focused on the reform of science education, we hear calls for changes in standards and educational policy, changes in the organization of schools, and changes in the roles of organizations outside of schools. In this article, we focus on learning environments as sites for change (Collins, Greeno, & Resnick, in press). Specifically, we describe ongoing work we are engaged in with elementary teachers in which we are designing learning environments that feature "guided inquiry."[1]

Despite reform efforts of the past, children learning science today are not likely to reach the goals espoused in current reform documents (e.g., AAAS, 1989) because their learning environments lack the focus and range of elements necessary to help students reach those goals. Contemporary goals of science education require not only that students learn the products of science (facts, laws, principles) but that they understand science as a principled process of inquiry. To reach these goals, students need to be involved in inquiring about the physical world over a sustained period of time. Moreover, they need to be part of directing some of the inquiry, and they need to participate in discussions about their means of inquiry and the significance of the results. These activities are just part of what determines a learning environment, a feature of schooling that plays a major role in constraining or enabling student learning.

To illustrate, picture a classroom with which you are familiar. What are the participants in this class doing? What tools (physical and mental) are they using to learn? With whom are the participants doing their work? What is the work like? What is the nature of the communication among the participants? What purposes are you able to derive for the activity of the group? These are just a few of the variables that determine the nature of the learning environment.

Our primary goal is that children understand the nature of scientific problem solving as the pursuit of meaningful questions through the use of procedures that are thoughtfully generated and evaluated. Contemporary learning theory indicates that such understanding requires the active construction of knowledge by the learner. What contributes to this active construction? Clearly, there needs to be ownership by the learner—a sense of responsibility for establishing and monitoring one's own learning goals. There has to be a context in which new or refined understandings can emerge from the learner's experience and activity. In addition, because learning arises not only from individual activity but also from social interaction, there has to be a context in which learners can practice the language and tools of scientific problem solving in socially situated activity (Brown & Campione, in press; Edwards & Mercer, 1987; Palincsar, Anderson, & David, 1993). Guided inquiry was designed to reflect these features.

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Guided inquiry attempts to blend the emphases of several science education reform efforts of the past. First, it assumes an inquiry-based approach similar to curricula developed in the 1960s, which were focused on discovery learning. In a discovery learning approach, students are involved in direct exploration and manipulation of the physical world. Integral to discovery learning are questions (teacher or student generated) about what and how to inquire.

Second, guided inquiry emphasizes the development of conceptual understandings of science, an essential feature of the conceptual change approaches first developed in the 1980s and still in development today. Conceptual change approaches acknowledge that learners bring previously constructed understandings about the physical world to their school science experiences, some of which may be contradictory to scientific knowledge; hence, science instruction must include opportunities for students to confront and wrestle with these disparities.

Distinguishing guided inquiry from historical approaches to science education is the assumption that it is important to use whatever knowledge students have in the process of building new understandings and that the process of building scientific knowledge will be facilitated by having many opportunities for learners to discuss and compare their understandings with others. In addition, guided inquiry is concerned with students having meaningful contexts for investigating the physical world, a viewpoint in common with the progressive education era of the early part of this century as well as the recent call for "authentic" learning experiences for students (e.g., Resnick, 1987).

Meaningful learning contexts do not often arise from science concepts such as kinetic energy or photosynthesis. Instead they stem from issues we encounter in our daily lives such as keeping things warm or keeping plants healthy. Guided inquiry begins with those concerns, and as part of a learning environment that supports the use of reading, writing, and mathematics in the service of learning about the physical world, learners develop knowledge and skills beyond that of the field of science.

Heuristics for the Design of Guided Inquiry

In the next sections, we illustrate guided inquiry by describing a planning and enactment heuristic developed by Magnusson that has guided our design and implementation of guided inquiry. Figure 1 depicts this heuristic graphically. Each term in the figure refers to a phase of instruction in which certain types of activities typically occur. In this way, the heuristic signals for teachers the kinds of activity in which students must participate during science instruction that are necessary to reach contemporary goals of science education. The lines with arrows indicate the progression of the phases of instruction.

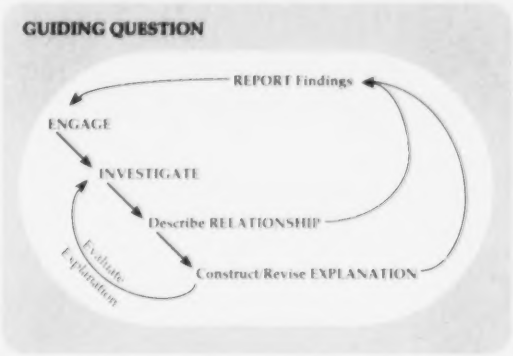

Figure 1. A heuristic for planning and enacting guided inquiry instruction in science.

Notice that some phases have two possible paths leading from them. In particular, the curved lines lead to a cycling phenomenon in which students participate in the same phases of instruction again, either in the same context or a different context. For example, the curved line that leads from the "describe relationship" phase indicates a cycle in which students explore the same or related questions or phenomena "only" to the point of finding patterns and describing relationships.

This progression illustrates the recursive aspect of instruction that is required to promote meaningful learning, particularly with respect to scientific inquiry, because one needs sufficient experiences with inquiring about the world before one can realistically begin deriving and testing meaningful explanations. In addition, this feature of "re-cycling" through phases of the instruction in relation to the same conceptual goals illustrates the important role of teachers because they determine the progression of phases and whether and how often re-cycling occurs.

We have explored the use of this heuristic with a group of elementary school teachers and their students, grades one through five, from two schools with student populations that are quite diverse relative

to socioeconomic status, ethnicity, and academic achievement. Our collaboration with the teachers began with a week-long institute during the summer of 1993. It continued through the school year with group and individual meetings, as well as electronic conferencing. We present this work as a chronology since the chronology reflects the planning and decision making in which good teachers routinely engage (Clark & Yinger, 1977).

Configuring the Terrain

One of the first decisions we confronted was determining the topic of inquiry. We were guided by the tenets that the topic be: (a) conceptually rich with regard to the opportunities it provided for meaningful inquiry that would yield understandings of enduring value, (b) flexible with regard to developmental issues, and (c) relevant to the lives of children so that it was both accessible and interesting to children. Our decision was also influenced by examining the local curriculum guidelines (in our case these guidelines were not especially constraining) as well as a selection of the national reform documents such as those produced from Project 2061 (e.g., AAAS, 1989, 1993). The general area of inquiry upon which we settled was *communication*.

Influenced by several contemporary approaches in which the topic of study is represented in the form of a general question that organizes and drives the investigative activity (e.g., project-based approaches described by Blumenfeld et al., 1991), we sought to represent the terrain of communication as a set of guiding questions. These guiding questions played an important role in linking together individual investigations and providing a reason for considering the relationships among the specific understandings derived from the investigations.

The superordinate guiding question that sprung from our discussions was: How and why do people and other animals communicate? Subordinate guiding questions were identified at each grade level and included the following: How has communication changed over time as a function of changes in technology? How does communication differ across cultures? What do animals communicate?

Determining the Conceptual Foci

Having identified the broad guiding questions, the next level of decision making entailed identifying the conceptual foci of the inquiry and the relationship of these foci to the guiding questions. These conceptual foci were also represented in the form of questions—we call them focus questions—and can be generated in collaboration with the students; however, the teacher needs to evaluate the constraints and possibilities afforded by particular focus questions.

For example, as we planned with those teachers who had selected guiding questions about animal communication,[2] we began to consider the importance of the choices made relative to which animals the children would explore. Typical focus questions in this area of study take the form of questions about specific animals (i.e., How do whales communicate? How do gorillas communicate?). While, at first blush, it may seem that any animal is as good as another as a focus of inquiry, the animal kingdom exhibits a wide variety of means of communication. This is an important understanding and one that would not be developed if the chosen animals communicated in basically the same ways.

Furthermore, an underlying concept in understanding animal communication is that organisms have specific structures (wet noses, echo-locators, large ears) to accomplish the functions they need for survival (e.g., locating food sources, finding mates, protection from predators), and that these are related to their habitat. Understanding structure-function relationships and the link to habitat is an important conceptual understanding in biology, and it would be illustrated better by selecting animals in different habitats who vary in the ways they communicate.

Compelled by the goal that children have the opportunity to learn about this relationship, we identified prominent modes of communication in the animal kingdom, such as sound, touch, scent, echo-location, and visual signals. With input from their students, the teacher then selected the animals with which the children together would investigate the structure/function relationship relative to these various modes of communication.

Engaging in the Inquiry

An important first phase of the specific activity of guided inquiry is becoming engaged in the inquiry. Part of that activity is to determine the specific problems or phenomena that are important to investigate in relation to the driving question. Determining an appropriate *specific* focus, and making sure everyone

understands the focus and its relationship to the guiding question, are important elements of this step. Teachers and students can work together to do this by determining focus questions that guide the investigation of the broad guiding question. When those aspects are monitored (by teachers and students), conceptual understanding is fostered.

For example, in the case of the first graders exploring animal communication, initial engaging activities included listening to an array of animal sounds, making predictions about which animals were making these sounds, and generating questions about how and why they made these sounds. The children then brainstormed and executed as many ways as they could conceive to communicate a series of messages to a set of classmates who were out of the classroom when the messages were being constructed. This activity led to discussions about the purposes for which we, as people, communicate, the modes by which we communicate, the advantages and disadvantages of our various modes of communication, and how our characteristics as humans shape how and what we communicate.

Investigating and Describing Relationships

The investigation relative to the focus questions is the next phase of guided inquiry and must be planned (by the teacher and/or the students), paying specific attention to what information or data need to be collected and how that will be achieved. This step may involve either first-hand investigations of physical phenomena or information gathering from secondary sources such as books or human experts. The point is to have a defined focus and to consider and understand the way(s) to get the required information, given the targeted goal of the inquiry (answering the focus question). An important result of this phase in which first-hand investigations are used is that the data students collect will have patterns, which they will need to determine and describe.

For example, during the exploration of animals that communicate through echolocation, students investigated several types of bats. During these investigations, they "discovered" that the relative size of ears and eyes, with respect to body size, differed greatly for bats of different species. Insect-eating bats had ears that were generally quite large relative to the size of their bodies while fruit bats had smaller ears but larger eyes. The children determined this from examining videos of bats, consulting picture books and children's periodicals (e.g., *Ranger Rick*), and having a close encounter with a frozen bat who serendipitously became available for the purpose of observing and describing bats.

To understand why this might be, the children made extensions of their own ears (using paper cones), which they used by changing the shape and size to investigate how the structure of their "ears" influenced what they could hear. Finally, the children learned about the habitat and prey of these species of bats. Discussions and debriefings conducted in hand with their investigations focused on the patterns the children observed and their emergent explanations for these patterns.

This phase is a hallmark of guided inquiry and is similar to the intent of a discovery learning orientation to science instruction in that it assumes that even young children can identify patterns in the physical world. It is to be distinguished from the succeeding phase shown in Figure 1, the task of explanation. Identifying patterns is an analytic process involving identifying objects or events that appear to be related, and determining the nature of their relationship. Teachers can guide students with respect to which topics or contexts afford them these opportunities, ones in which they can "discover" something about the world.

Constructing an explanation, on the other hand, is an inductive process that draws upon one's own imagination and creativity. It is not a case of something to be "discovered"; hence, when students construct explanations we cannot expect them to match what scientists have constructed. This is especially true for young children or learners who are new to exploring a particular aspect of the physical world. We do not see this as problematic, however. Instead, we see it as an opportunity to discuss the issues involved in determining the "power" or worth of an explanation.

Given the differences in these phases, we suggest that care be taken not to focus on deriving explanations too soon. As stated earlier, learners may profit from cycling through the first three phases several times as their investigations are refined and their understandings developed. Furthermore, once explanations have been initially discussed, students can profit from conducting more investigations and comparing the patterns and possible explanations they

constructed from the new contexts with those of the old, before settling on an explanation they would like to test (the next phase depicted in the heuristic).

The development of understanding from these phases of the guided inquiry approach partly results from participation in the reporting phase, in which groups of students who have been investigating together publicly describe and discuss their findings with the teacher and the other students. During these opportunities, students can discuss important issues in the investigative process such as possible errors in conducting investigations, missed observations, or insufficient records of what was observed. Moreover, public reports require students to make and defend statements about their understandings relative to an investigation, and these provide occasions for examining one's thinking and sense making.

If students move through these initial phases several times, it conveys the message that it is important to examine one's thinking and understanding and that it can change and evolve over time. In this way, students gain confidence in representing their thinking and examining it. In addition, when students publicly share their results, the need for vocabulary and a common language to communicate their ideas becomes salient. Thus, this provides an important opportunity for the teacher to support and guide the students in becoming knowledgeable about the appropriate scientific terms to use to facilitate their communication.

Constructing Explanations

It is likely that students will begin to venture explanations during the initial phases of the inquiry. When this happens, the teacher guides students to the recognition that constructing an explanation is cognitively different from identifying patterns in the physical world, and that it is important for them to keep examining their ideas in relation to the new contexts they explore, and work toward constructing the best explanation they can to account for the patterns they identified. This activity represents the theory- or model-generating phase of scientific activity, and addresses the important "why" goal of science.

At some point, however (when the teacher or the students judge that they are ready), the class should formally discuss the explanations that have been generated. This is an opportunity for the teacher to model the norm of science that explanations, models, and theories are evaluated with respect to their adequacy in accounting for already identified patterns as well as the possibility of predicting new ones (Duschl, 1990).

It is also important for students at some point in this phase to consider whether there is accepted scientific knowledge that is relevant, and if so, what it is and what it means. The difficult balance here is for teachers to allow students freedom to build from their own understanding and construct their own explanatory ideas while also finding out about currently accepted scientific explanations and considering how they relate.

One element that is important to this approach but not indicated in the heuristic is the assumption that guided inquiry instruction will take advantage of the use of technology to render visible ideas that are important for the students to consider. For example, microcomputer-based technology for detecting and analyzing motion was used to help students investigate the concept of echolocation. A microcomputer peripheral called a motion detector was used to simulate echolocation. This was possible because a motion detector sends out a signal, receives its reflection, and uses that information to determine the distance to the object, which is represented on a graph shown in real time as the detector is being used.

This is just like the process used by animals who echo-locate, and students can investigate how the process works by placing and moving objects different distances from the detector, and viewing the results on the graph provided by the computer. By investigating how the detector works, students were able to gain a greater understanding of the concept of echolocation. This was just one way in which technology was used to support the development of conceptual understanding, an important goal of guided inquiry instruction.

Finally, once students have constructed explanations they want to test, a primary way for them to test the adequacy of their ideas is by considering a new context in which the explanation is relevant, predict what would happen if the explanation is valid, and conduct an investigation to test the prediction. This is the last phase shown in the heuristic for guided inquiry, and completes the cycle of activity in this approach. Our intent is not to suggest that this phase should be a part of all series of investigations, but that when feasible and appropriate, it is an important

part of the thinking process that occurs in establishing scientific knowledge.

During the study of animal communication, this phase of instruction did not occur but might be something like the following. In this specific program of study, a useful pattern for children to observe and explain is that organisms have different physical characteristics (structure) for accomplishing the same goal (e.g., detecting prey). We previously described, for example, that the ears and eyes of bats who eat fruit (a stationary target) are different from those of bats who eat insects (typically a moving target). The students could examine the adequacy of that explanation by selecting a physical structure on two different organisms (e.g., two birds with different types of beaks), predict what they think it allows the organism to do, given its structure, and investigate (in this case, read about) what that structure allows the organism to do. This is not a test of an explanation in the scientific sense, but it illustrates the idea expressed in the heuristic.

The Teachers' Learning Environment

In the introduction to this article, we argued that an important context in which to consider school reform is the learning environment in which teachers and children go about their activity. We then presented the guided inquiry heuristic as a conceptual framework for the design of a learning environment that supports the meaningful learning of science. We now reflect on our experiences implementing this learning environment in elementary classrooms. We draw specifically on our experiences with a first grade teacher engaged in the animal communication study.[3] The teacher, Joyce Page, has 25 years of teaching experience.

As a backdrop, it is helpful to consider the extent to which guided inquiry represented a "reform" in Ms. Page's instruction. As she described it:

> I was very intimidated when we met last fall and started talking. . . . I'm not very good at science teaching, and science is what gets forgotten in my first grade curriculum. . . . It's something I've been concerned about and wanted to do something [about]. It's always been a feeling of, "How do I get science into it"?

This was a common sentiment expressed by our elementary teachers who, with good reason, feel a strong commitment to the language arts. The research of McLaughlin (1990) and others who have studied organizational change speaks to the importance of presenting innovations, not as independent entities or isolated activities but rather in an integrated manner. Furthermore, we were mindful that to bring about change in classrooms, there would have to be occasions for teachers to be the constructors of knowledge (cf. Richardson, 1990). Our goal in the design and presentation of the guided inquiry heuristic was to prepare a tool—informed by theoretical principles regarding the teaching and learning of science—that offered instructional coherence and could be appropriated and adapted by teachers in the service of teaching for principled understanding.

Throughout the year, we asked Ms. Page to comment on the role the heuristic played in this innovation; our interest was in the extent to which the heuristic rendered some fairly complex and demanding instructional ideas accessible to teachers. "Direction is probably the key thing," she noted. "As long as I'm focused and I know where I'm heading, it's okay." Ms. Page found "direction" in the key or guiding questions (How do animals communicate? How does animal communication reflect structure/function/habitat relationships?) as well as in the "structure" afforded by the activities inherent in the heuristic; moreover, and very importantly, she felt comfortable adapting it.

> We did not follow completely what was supposed to be, but I guess that's okay too. We adapted as we went along, changed it, added to it, deleted from it. . . . That was good for me. . . . I was able to see where the kids were. . . . It was good for them.

In addition, while this feature of guided inquiry has not been the focus of this article, there are indeed multiple opportunities for students to use reading, writing, and oral language in meaningful ways in the course of conducting the investigations integral to guided inquiry. In fact, by the conclusion of her first year with guided inquiry, Ms. Page observed:

> I was truly amazed to experiment and sort of stumble into the fact that you can teach everything else through science very easily. And now I'm finding the math book cumbersome. I'm finding we don't get as much done in the reading books, yet I'm also finding that my children are able to do math and reading as well as they used to when I spent so much time with that. . . . And I know the enthusiasm level of my students is far greater.

In addition to the design features of the heuristic, several principles guided our work with teachers. The

first is that change in classrooms be conceptualized as a process rather than as an event (Fullen, 1991). A corollary to this principle is that the process of change is developmental in nature (Loucks-Horsley & Stiegelbauer, 1991). These principles suggested that there would have to be multiple occasions for the university and school faculties to reflect on and reconceptualize their instructional beliefs and practices. Some of these occasions included: the summer institute, the biweekly planning sessions, and the electronic-mail conferencing, but, interestingly, one of the most important occasions emerged from the daily journal writing (briefly documenting the instructional activities, noting students' responses and the teachers' impressions of the activities). Ms. Page commented:

> This [journal writing] was the thing that intimidated me most because the thought of having to do something every day after [teaching]—I thought, "that's crazy." But it was addictive. . . . It was helpful to me in that it . . . channeled my thinking, and a lot of times some pretty creative things came from writing it down on paper, solutions on how to solve a problem. [For example,] in the middle we got a little dry . . . we got a little too factual. . . . And putting it down on paper helped me see that's what was going on.

Along with the conceptual support provided by the heuristic and the social support built into the innovation process, Ms. Page called our attention to several other factors that facilitated her implementation efforts. She noted that there was an excellent match between the instructional goals represented in the heuristic and its accompanying program of study and the outcomes for which her students were being held accountable. In addition, the administrators at both the building and district levels were publicly supportive of her efforts. Our experience with Ms. Page and the other teachers with whom we worked this year has increased our awareness of other factors that will require additional attention.

We have learned to conceptualize significant change in learning environments as taking place over years, rather than weeks or months. In fact, at the end of her first year implementing guided inquiry, Ms. Page spoke emphatically about the need to engage in the same general course of study on animal communication the subsequent year. She recalled the fatigue she frequently felt during this first year of implementation and noted "the 1,000 problems" that could not have been anticipated but for which she could now plan (at least for a subset of these problems), and her developing sense of "what works."

Ms. Page also noted that for the first time in her teaching experience she received questions to which she did not know the answers.

> I was taught way back that when you don't know the answer to a question, you should be willing to admit it to a child and then go find out. But frankly, I don't think [the children] ever asked me questions I didn't know the answers to. This year they did. I'm sure that's why there was such a closeness, because I readily admitted, "I don't have a clue. . . . Let's go find out."

The issue of teacher knowledge continues to be central to our research. We know that teachers need to have knowledge to help students build understanding. While recognizing that subject matter knowledge is necessary, we do not know how much is sufficient. We also know that pedagogical knowledge influences the extent to which teachers' subject matter knowledge can be rendered useful to students. For example, teachers need strategies to elicit students' ideas, recognize and refine their emergent understandings, and scaffold students' learning (Magnusson, Krajcik, & Borko, in press). We anticipate that our collaborative work with teachers in guided inquiry will provide a fruitful context for pursuing the teacher knowledge questions.

Conclusion

As we reflect on our experiences in planning and implementing guided inquiry with teachers, *map-making* strikes us an appropriate metaphor for this process. During the planning, the general terrain is identified and represented in the forms of the superordinate and subordinate topics of inquiry with accompanying guiding questions. The richness of the terrain is, to an extent, a function of the conceptual foci that constitute the terrain. Supporting the students' explorations of the terrain are the activities (first- and second-hand investigations, discussions, and presentations) and resources (e.g., books, general technology, experts) to which the students have access.

Having established the general trajectory to be pursued within the terrain, the students must now join the teacher in the actual map-making, with the role of the guide shifting opportunistically between the teacher and children. For with the enactment of the instruction, the journey itself becomes the travel

story to be written by the teacher and students. The navigators chart their courses, documenting their journey, reflecting on where they have been, and proposing and weighing future directions.

Of course, the very act of navigating changes the nature of the terrain. For example, as children bring their own life experiences to the navigation, and raise their individual and joint questions, new bridges and roads are built, connecting what at one time appeared to be isolated places—disparate understandings. Enabling children and teachers to travel, with understanding, well-traversed paths represented by the received scientific canon as well as to forge their own courses toward understanding seems a worthy goal of science education reform.

Notes

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1. The authors gratefully acknowledge the contributions of the 1993-94 guided inquiry design team, including Susan Keeney, Mark Templin, Bob Boyle, and Kira Wilkins-James.
2. Technically, this program of study should have been referred to as non-human animal communication because it confined itself to the study of animals other than humans. For simplicity we referred to it as animal communication.
3. The data from which we draw in this section are derived from the journal the teacher maintained, as well as from a series of three formal interviews and informal conversations held during joint planning sessions.

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Navigating Change in High School Science and Mathematics: Lessons Teachers Taught Us

THE SEAS HAVE BEEN ROUGH for teachers of science and mathematics these past few years. Business leaders, politicians, and university professors all have demanded that high school graduates exhibit increased skills in science and mathematics and better preparedness to cope with an increasingly technological world. They point out that students' achievement—or, to be more precise, students' lack of achievement—in science and mathematics undermines the nation's competitive edge and negatively impacts the American economy.

Researchers provide evidence to support the perception of crisis and the calls for change: The 1990 National Assessment of Education Progress (NAEP) math report, for instance, showed that "only 5% of high school seniors showed an understanding of geometry and algebra. Fewer than half of the seniors showed a thorough grasp of decimals, percents and fractions" ("Reinventing Math," 1992, p. B4). Similar claims of reduced understanding in science abound. To compound the problem: In both fields, fewer students are taking higher level courses.

Work in cognitive psychology further supports the call for change (e.g., Anderson, 1989; Glaser, 1984; Resnick, 1987). This work calls into question traditional views of learning and traditional approaches to teaching. It suggests that students must actively construct their own understandings, that they should not sit passively as teachers "teach," nor should they mindlessly follow detailed procedures laid out in a lab book. Teachers, work in cognitive psychology suggests, should behave more like coaches than choreographers. Rather than carefully choreographing the learning process in advance, their task is to set up the learning game and provide feedback and advice at opportune moments.

In the midst of this turbulence, many teachers feel themselves pitching and rolling. They find few navigational charts, however, to help them understand how they might change what they are doing.

The Coalition of Essential Schools (CES), an organization of over 800 restructuring schools, has both listened and contributed to the national dialogue about the need for change in high schools. Understanding how change takes place in schools and their surrounding systems is part of CES's regular work. In a recent study of schools deeply committed to change, researchers found that science and mathematics teachers appeared much more resistant to change than teachers from other disciplines.[1]

When asked why this might be so, science and mathematics teachers suggested that, despite the external call for change, the constraints preventing them from restructuring were very real. In order to study this initial finding more thoroughly, a CES researcher joined

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forces with a researcher from the National Center for Science Teaching and Learning (NCSTL) to design a project that would allow us to work collaboratively with science and mathematics teachers to better understand the constraints they experience and to try to find some navigable passages around or through these constraints.

The Joint Project

Seventeen science and mathematics teachers from five very different CES schools in four different settings (urban, suburban, rural, small town) were invited to investigate both the barriers to reform and, for some, their disinterest in change. These particular teachers were selected because, when we observed them in action in classrooms, they appeared to represent a cross section of secondary math and science teachers: Some were traditional, others innovative; some were well informed about national reform movements, others had little exposure to reform thinking; some seemed eager to change, others appeared reticent and even resistant.

The project was undertaken during the 1992-93 school year and the summer of 1993. The project was divided into two phases.

Phase I

At the outset of the project, teachers read and discussed the National Council of Teachers of Mathematics (NCTM) standards; *Science for All Americans* (Rutherford & Ahlgren, 1990), the publication developed from The American Association for the Advancement of Science's (AAAS) Project 2061; and reports about the National Science Teachers Association's (NSTA) Scope, Sequence and Coordination project. They also listened to and interacted with consultants who had worked on each of these projects. After familiarizing themselves with the projects, participants worked to distill the common recommendations of these national reports. Participants uncovered four more-or-less common recommendations:

1. Science and math curriculum content should be reduced so that students have the time to learn concepts and skills thoroughly.
2. Students should be able to apply skills, concepts, and research methods to fresh circumstances as a way of demonstrating their thorough understanding.
3. Disciplines should, in some way, be integrated in order to help students better understand the relevance of academic knowledge for solving real world problems.
4. Students should be able to formulate problems, discern potential solutions, conduct experiments, and draw conclusions.

While simple, these four points of agreement suggest radically different approaches to teaching and learning than exist in most secondary schools in this country, even secondary schools committed to change. To help participants envision what these relatively abstract recommendations might look like in practice, we also, in the initial phase of the project, walked participants through a problem-based learning (PBL) activity. Problem-based learning, as we are using the term, is a pedagogical strategy that was first developed in the field of medical education. The strategy focuses students' attention on an ill-structured problem, that is, a real world problem that students not only must solve but also, as a precursor to finding a solution, must more fully define and articulate from the fragments of data they are initially given.

For some advocates of problem-based learning, ill-structured problems must also lend themselves to multiple solutions. Even for those who do not make this characteristic a defining property of ill-structured problems, however, problem-based learning is at the opposite end of the teaching strategy continuum from the traditional, problem-oriented instructional strategy labeled guided discovery, the strategy in which teachers structure things so that students discover what the teacher wants students to know.

In problem-based learning, teaching is a far more serendipitous, improvisational, and responsive process, a process in which students must play a much more proactive role. Teachers, for instance, do not normally supply relevant information at opportune moments; students must figure out for themselves what to ask for and make a request. Only then will the teacher respond.

With respect to its relative open-endedness, problem-based learning is closer to the inquiry-based approaches such as those developed by the Elementary Science Study (ESS), a curriculum development project in operation during the 1960s. The major difference is that in problem-based learning, students tackle problems situated in real world contexts and are cast in life-like roles.

In the problem-based learning activity that we used during Phase I, for instance, Bill Stepien, a

consultant from the Illinois Mathematics and Science Academy, provided participants (cast in the role of physicians) sketchy medical test data about a pregnant woman named Jane and a note indicating that Jane and her husband have scheduled a consultation with the doctor to talk about the significance of these data for Jane's pregnancy. (The data suggest the possibility of encephalitis, but participants were not told this.)

The consultant then posed three general questions that participants—in their consulting physicians' roles—needed to answer in order to provide appropriate feedback to Jane and her husband: What do we know? What do we need to know? How can we find out what we need to know? As the participants confronted these questions, they asked the consultant for additional information. He had brought with him articles on a variety of topics, Jane's medical records, and a wealth of other materials, and he provided these if and when participants made appropriate requests.

Phase II

The second part of the project required that each teacher generate an action research project to explore some aspect of the recommendations for change they had gleaned from reading reform documents from the major national organizations in the fields of science and math education and by interacting with consultants from these groups. We asked participants, in other words, to try to understand—and help us better understand—both the constraints that inhibited efforts to implement one or more reform ideas and the factors that facilitated change.

The projects the teachers designed varied with respect to both topic and methodology. Two science teachers, for instance, surveyed all juniors and seniors in the high school in which they worked to determine why students took—and, more important, why so many students decided not to take—chemistry and physics, while another team of teachers conducted structured interviews to determine how K-12 teachers in their district responded to the NCTM standards. Nine of the seventeen teachers, however, chose to experiment with problem-based learning. Their experiments differed greatly: Some explored existing problem-based learning units; most developed their own. Among those who developed their own units, some started from scratch while others adapted units they had taught in the past, putting previous plans, in other words, in a problem-based format.

Some teachers worked alone, others planned and, in some instances, even taught in teams. Some limited their experimentation to their own classrooms; others tried to interest their colleagues in the strategy and utilize the strategy to promote reform at the building level. Finally, one team of three teachers used a pretest-posttest research design to determine impact on student learning, while the remaining teachers employed a more open-ended qualitative approach to collecting and analyzing impact and process data.

Participants' investigations were conducted from February through June in their home schools and districts. The group gathered again in the summer to report their findings and consider their significance for other science and math teachers.

What follows is a discussion of some of what we learned as we looked across the projects the teachers undertook (especially those built around problem-based learning), reviewed transcripts of in-depth interviews conducted throughout both phases of the project, and reread the detailed notes taken at meetings of the group. The findings are revealing in that they call into question our initial assumptions about science and mathematics teachers' resistance to change. They also problematize the school change study's finding about the significance of external barriers to change.

The Value of National Reports

All of the participants were interested in and reported benefits coming from studying the national reports about educational reform generated by NCTM, NSTA, and AAAS. Some of the teachers were unaware of these reports and consequently felt better informed once they had seen what the various national organizations were recommending. Others who had read, or at least had knowledge of, one report found that reading a second report was enlightening. Science and math teachers both suggested that reading the reports of a second discipline (e.g., science teachers reading the NCTM standards) helped them appreciate the commonality of recommendations across fields and made them aware that other groups were endorsing principles compatible with and, in many instances, identical to those being advanced by the Coalition of Essential Schools.

What function did this new knowledge base have? Teachers indicated the reports gave them confidence and legitimacy as they went about the business

of explaining and making the case for reform to colleagues, administrators, and parents.

One thing the reports did not appear to do: They did not change the teachers' opinions about the need to reform. The majority of the teachers we assembled were already committed to the sort of reform initiatives endorsed in the reports they reviewed, and even the skeptics in the group did not quarrel with much of what was said in the reports. For the most part, the reports' recommendations were general and relatively abstract, more noble sentiments than operational plans. As is often the case, the devil—or at least the disagreement—is in the details. Problems, in other words, do not arise until teachers begin to answer—in a relatively concrete way—that bottom-line question: "What do I do Monday?"

The Bottom-Line Barrier

Most of the teachers we worked with, in fact, had difficulty answering the question, "What do I do Monday?" This difficulty—this absence of concrete strategies for operationalizing reformers' vision—appeared to be the most fundamental barrier to changing teaching and learning in science and mathematics classrooms. Most of the teachers with whom we worked were not so much resistant to change, it turned out; they generally agreed with reformers' critiques of current practice and embraced the general vision of more student-centered, relevant, integrated, and hands-on/minds-on classroom practice the reform reports advanced. Even among this group, however, change was frequently minimal, at best. The reason: Most teachers, quite simply, had trouble figuring out what to do and where to start. The images provided in the reform reports were not specific enough to help teachers know how to begin, much less sustain, the process of integrating subject matter, moving from didactic instruction and cookbook laboratory work to more meaningful problem-centered work, and making classroom learning less a process of rote memorization and more a process of meaningful inquiry and exploration.

There was a real need, therefore, for specific approaches and techniques before teachers could enact the general visions of change the national reports promoted. Indeed, a knowledge of specific strategies appears to be a necessary—albeit not necessarily a sufficient—precondition for reform. This appears to be the case even among teachers who worked in schools that were well steeped in reform rhetoric and who had appropriated reformers' rhetoric and ideas and made them their own.

It was not accidental that the majority of teachers with whom we worked decided to build their action research projects around the strategy of problem-based learning or that several of the teachers who decided on other projects also employed (and, in some cases, continue to employ) this strategy in their classrooms. The problem-based learning strategy was treated like "manna from heaven." After they had worked through the Jane's baby problem, many of the teachers behaved as if they had undergone something reminiscent of an "ah-ha" experience. They finally had an image—a quite concrete image—of what they might do Monday instead of what they had traditionally done. They finally had something the reform literature did not provide but was essential to doing what reformers (and they themselves) wanted done. Problem-based learning, in short, was a bridge over a fundamental barrier to change in science and mathematics classrooms.

Techniques as Heuristics Rather Than Recipes

Having just called for more specific strategies and techniques, we should quickly add an important caveat: Teachers—at least the teachers with whom we worked—did not appear to want recipes or formulas. The fact that so many of the teachers who opted to do problem-based learning designed their own problems rather than using the problem-based learning materials provided by our consultant suggests, to us at least, that they were more interested in techniques that are fairly general heuristics rather than teacher-proof standardized operating procedures. With limited training and only a handful of tools (the single example of a problem-based learning experience, described above), and despite some concern and even anxiety on the part of some about whether they were doing it right, the teachers in our project fashioned a diverse set of problem-based learning experiences themselves.

One team, for instance, generated a month-long, integrated science and mathematics project on the effects of radon on an unborn child—an issue that was a concern in their locale at that time. In another instance, a chemistry teacher engaged his students in a lengthy investigation of infertility and hormones, which concluded with a mock consultation between

doctors (played by students) and a couple (played by faculty) who had not been able to conceive. In the development of this project, the teacher consulted with a doctor friend, constructed a medical history for the couple, and compiled a mini-library of medical texts with which students might work.

Still another teacher developed a problem about a chemical spill in a river near his school. In this project, students worked in teams first to identify what the initially unidentified liquid was and what dangers it posed and then to make recommendations to the mayor on how the city should proceed in dealing with this problem.

Not only were teachers in our project able to fashion their own problem-based learning units with only the sketchiest of technique and very limited experience and training; the data suggest that what they fashioned was of high quality and had a positive impact on students. A consultant from a national organization that develops problem-based learning units, for instance, judged the chemistry teacher's fertility unit equal to the best units his organization had produced. Evidence collected by teachers doing the radon unit suggested increased student learning and heightened student motivation. And a before-and-after survey of students who participated in the chemical spill project showed that the number of students who felt that science applied to their lives outside of school rose from 65 percent to 89 percent after the unit was taught.

The units the teachers developed were particularly successful in motivating students who had not traditionally done well in school in general and the teachers' classes in particular. One average to below-average student who participated in the fertility project, for instance, carefully researched the problem and generated a viable diagnosis other than the one anticipated by the teacher who designed the project. This incident speaks both to the impact of the teacher's work on students and the teacher's skill in constructing problem-based learning experiences. As noted, ill-structured problems that lend themselves to multiple solutions are prized among advocates of problem-based learning. With only minimal training and technique, this teacher managed to create such a problem for his students.

Whether all teachers will be able to do this—or whether they will even want to do this—we cannot say. We do know, however, that most of the teachers who participated in this project opted to fashion their own projects around ill-structured problems that were meaningful to them and their students. We also know that some of the teachers have continued to do this 2 years after the project was completed. These facts should temper our earlier call for more concrete strategies and techniques: At least some of the strategies and techniques provided by reformers should be more heuristics than recipes, for many teachers can and appear to want to construct their own learning experiences for their students.

Giving teachers heuristics rather than recipes enables teachers to tailor learning experiences to students' interests and to issues significant in the context. Teachers also gain some ownership and control over what they do. This is a necessary precondition for professional status and, we suspect, an important incentive for teachers to do their work well.

External Barriers

As noted above, the assumption that external barriers (e.g., high-stakes standardized tests, existing organizational structures, state and district policies) prevented science and mathematics teachers from changing was central to the design of this project. We wanted to explore these barriers and to discover possible ways to circumvent them. We discovered in the course of doing the project, however, that our initial assumption about the significance of external barriers—while not totally wrong—was a bit glib and, at the very least, needed further clarification and even some qualification. Our work, in fact, revealed the following points with respect to the significance of external barriers.

First, teachers tended to overestimate the significance of certain external barriers. Some barriers, in short, were more in teachers' minds than in reality. The perceived problems posed by standardized tests would be one example. Many teachers in both the CES's School Change Study and in this particular project indicated they were reluctant to change their teaching practices because they were concerned about their students' performance on high-stakes tests such as the SATs, the ACTs, and, for those teachers in New York State, the New York Regents examinations.

We pointed out that the first two examinations on this list were explicitly designed to be curriculum free, i.e., they intentionally did not test the content of any particular curriculum. Furthermore, the science

section of the new version of the ACT explicitly focuses on scientific reasoning rather than factual recall (i.e., the information one needs to answer the questions is provided) and even the quantitative section of the more traditional SAT has a problem-solving focus; thus, to the extent that *any* curriculum can significantly affect students' performance on these curriculum-free tests, it is reasonable to assume that a problem-based curriculum might have a more positive impact than would a traditional program.

Even the New York Regents examinations—examinations expressly designed to test students' knowledge of specific curricula—turned out to be less problematic, at least for the teachers involved in our project, than had been traditionally assumed. As we explored this constraint with teachers from the school in New York State, we discovered that their school was part of special group of schools that could offer its own more performance-based regents exam in place of the standard paper and pencil exam administered by the state. At the time of our discussion, they simply had not taken advantage of this opportunity. Eventually they did and, in a follow-up visit to the school in October 1994, we observed an exciting, teacher-developed, problem-based learning experience in a physics class—an experience that was similar to tasks students would be expected to perform on the substitute regents exam the physics teacher created.

Not all external barriers disappeared so easily, of course. Some of the teachers in our study worked in schools and communities that had very real barriers to change. Despite these barriers, however, we found that all teachers who wanted to do so were able to change the way they taught, at least on a short-term basis.

Some of the teachers who were able to change their teaching practices most dramatically, in fact, worked in communities that were among the nation's poorest (a frequently cited constraint; Donmoyer & Kos, 1993) and in school districts that had reputations for being among the most bureaucratic in the nation. These teachers had a knack for focusing on the positive, and their positive orientation served as a self-fulfilling prophecy.

Ironically, the poverty in the surroundings in which these teachers worked could even be seen as a factor facilitating change. Parents of the students these teachers taught were not clamoring for advanced placement courses, and few if any parents expected their students to go to Stanford or Yale. Indeed, the only way society's low expectations would not become self-fulfilling was if teachers would adopt innovative practices. The specific practices these teachers employed—involving students in original research and sending them on internships to science-oriented industries—turned out to be tickets to a college education, and also frequently led to students receiving college scholarships.

But how did these innovative teachers avoid the pernicious constraints of bureaucracy? In one instance, a teacher used her district's school-within-a-school initiative to insulate herself from bureaucratic rules and regulations. With colleagues from other disciplines, she created, in essence, an island within which she and her colleagues had considerable control. Other teachers simply ignored the bureaucracy. As Barone (1983) has noted, when a bureaucracy is large enough and impersonal enough, a person can hide within it and do his or her own thing, sometimes to the benefit (and, undoubtedly, also sometimes to the detriment) of students.

The teachers we have been talking about, of course, are exceptional. In traditional quantitative studies, they might even be classified as outliers and not included in the data set being analyzed. We found, however, that even more typical teachers could overcome some very real inhibitors to change, at least on a short-term basis. One team of teachers, for example, came from a truly troubled school where faculty morale was low, where it was not unusual for half the student body to not return to school after they went out for lunch, and where administrators refused to make rather obvious policy changes to try to correct some problems (e.g., requiring students to stay in school during their lunch period to counteract afternoon absenteeism). Despite having no common planning time, three of the teachers in this school planned a rather sophisticated, problem-based learning unit about radon, and each of the teachers taught the unit to one or more of her classes with considerable success.

These three teachers also provide evidence to support the third point we want to make about external barriers: Although most external barriers can be overcome in the short run, external barriers can make it extremely difficult to sustain reforms over the long haul, much less to institutionalize them. The three

teachers discussed above, for example, despite their pride and enthusiasm about what they had done in their problem-based learning unit on radon, found it difficult to continue to use the problem-based strategy. One teacher who attended a summer workshop at a science laboratory did attempt to translate the workshop's content into the problem-based learning format with some success during the subsequent school year, but she found it difficult and unsatisfying to do this alone. Without a common planning period, in other words, it was difficult to work with colleagues who were themselves overwhelmed with trying to solve the widespread school problem of student absenteeism on their own as well as a host of other problems that fall back on teachers in schools that do not work.

Even among "superteachers" who were successful at sustaining innovative practices over a considerable time period, we worried about the costs that had to be paid to do this. We saw too many teachers having to teach too many classes to too many students and, in the case of teachers working in schools-within-schools, having too many administrative and quasi-administrative responsibilities, as well.

In the same district, we saw department chairpersons for each curriculum area in each high school. These remnants from the district's hierarchical past had virtually no teaching responsibilities and, since the school-within-a-school had been initiated in the district, very few other responsibilities, as well. This group, however, did have considerable political clout, enough clout, in fact, to insure that the district's scarce resources would continue to be used to perpetuate a role that now seemed to be an anachronism.

On the other hand, we saw what could happen when political clout was used to bring about and sustain reform. A superintendent from another district was concerned that her teachers, as part of this project, had designed action research studies that involved only gathering information from students rather than experimentation with different approaches to teaching. When the teachers came back to the district after our group's meeting at which the projects were designed, she talked with the teachers and explained that she expected that the gathering of information would simply be a precursor to experimentation at the classroom (i.e., at *their* classroom) level.

This same superintendent also went to bat for her teachers when the state department of education initially balked at a request to let teachers in the district design their own regents tests, something they were technically allowed to do. The superintendent threatened to publicly withdraw her district from the group of select schools the department had established if department officials refused to fulfill commitments it had made. The district's school board as well as its superintendent has had a long-term commitment to reform and to altering barriers that inhibit change. This agenda has been embraced by other administrators and teachers as well. Recently, for instance, the high school altered its schedule to provide more time to facilitate the sort of active learning reformers prize. This is one of many efforts taken in this district in recent years to support the change process.

It should not be surprising, therefore, that in this district, problem-based learning is still being used nearly 2 years after our project had been completed. On a follow-up visit to this district in October 1994, one of the authors observed a sterling teacher-developed, problem-based learning unit being "taught" in a high school physics class.

To summarize, our project suggests that we may initially have overestimated the role played by external barriers in inhibiting reform. We certainly discovered other viable explanations for what appeared to be teacher resistance, and we clearly underestimated the ability of teachers to overcome external barriers, at least in the short run (particularly if they have the sort of peer support this project provided; see Hiller, this issue). The significance of external barriers, however, should not be downplayed when our concern is sustaining and especially institutionalizing change.

Inherent Barriers

Our final insight relates to potential problems inherent in reform rhetoric itself. Science and math teachers' resistance to change, according to this view, may be a reasonable and rational response to ideas that work in the humanities but are problematic for the fields of science and mathematics education.

We should quickly add that our findings on this point are tentative. We are, in fact, engaged in a second joint project to explore this matter further. At this point, what we have to say about inherent barriers must be viewed in the context of hypothesizing. Since this hypothesizing turns the problem we were initially investigating on its head (i.e., our

solution becomes part of the problem and actions we initially coded as problematic can now be coded as efforts at a solution), we felt obligated to at least discuss this matter, even in a tentative way.

Our first inkling of a potential problem came after teachers presented reports of their problem-based learning projects at the second meeting of the group during the summer of 1993. Everyone in the room was impressed and pleased; there were congratulations all around. Then one teacher who had not done a problem-based learning project noted that all the math used in the projects was either arithmetic or statistics. This observation led to a question: Can projects be designed that can be used to teach higher level mathematics courses such as calculus? Similar questions were raised with respect to higher level science courses such as physics, which had not been used as test sites in the first round of action research projects.

The group, at its meeting, tried to generate problem-based learning scenarios for higher level math and science courses. The group, however, was not able to do this. Two rival hypotheses were developed to explain this lack of success. The first hypothesis was that conference participants lacked the necessary knowledge base to complete the task. Although many participants knew the content of higher level math and science courses and some, in fact, taught these courses, no one had extensive experience with applying this knowledge to real-world, ill-structured problems. The second hypothesis was that problem-based learning is not an appropriate pedagogical strategy for high-level mathematics and sciences courses. Although engineers and their applied scientists and mathematicians certainly use higher level math and science to solve real-world, ill-structured problems, students must first be initiated into a new way of thinking before they, too, can do this. Only after students undergo an extended initiation process in which they are exposed to the often counterintuitive thinking of the scientific disciplines can they begin to use disciplinary knowledge to solve real-world problems.

The teacher in our group who was most resistant to change was a particularly articulate spokesperson for this second hypothesis, and we believe this hypothesis should not be dismissed too cavalierly by educational reformers. Indeed, one can certainly find support in the science education literature for the view that thinking and problem solving in scientific disciplines is fundamentally different from thinking and problem solving in the real world (see, for example, Bereiter, 1994; Cobb, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994).

As we noted above, we have taken the inherent problem scenario seriously and are currently analyzing data from a second project designed to test the limits of problem-based learning for teaching higher level math and science. In this project, teams of science and math teachers from the first year project and another National Science Foundation-funded teacher education project currently being undertaken by CES worked with applied scientists and mathematicians from Brown University to try to develop problem-based learning units that can be used in higher level science and mathematics courses. Their work was then critiqued by other mathematics and science teachers. After appropriate modifications were made, teachers attempted to use the activities in their own classrooms and reported what happened.

Again, this discussion about problems inherent in reform rhetoric should be viewed in the context of hypothesizing. There is much to be sorted out and tested here. We have just begun to engage in this process.

Conclusion

In order for teachers to navigate change in science and mathematics classrooms, they must set a course that veers away from many of their own most familiar routes in favor of one that sails to new horizons. Moving from rote memorization to real-world application, from predefined content to untidy problem solving, and from working in discipline-bound domains to integrating discipline-based knowledge requires traveling on uncharted, often turbulent seas. In the project described here, we tried to get a better understanding of the barriers teachers who make this journey are likely to encounter. We tried, in other words, to get beyond glib assertions about teacher resistance and teachers' sometimes untested claims about external barriers.

In the course of this project, we learned many things. Here we have focused on several ideas that seem particularly significant to us. First, we learned that teachers—at least the teachers with whom we worked—were not so much resistant as they were lost at sea. The national reform reports provided a general sense of the direction in which to head, but teachers were somewhat immobilized by the absence of specific procedures for getting there.

Specific procedures, however, should not be too specific. Each of our teachers was sailing in her or his own somewhat unique environment and adjustments were needed to accommodate this uniqueness. The teachers we worked with were more than capable of making these adjustments, of tailoring strategies to the needs of their students and issues relevant to their particular communities.

We also learned that the environmental constraints on moving forward were not necessarily as great as we—or most of the teachers—initially believed. Still, for some teachers in less privileged situations, constraints in the external environment should not be underestimated, particularly if we are concerned about sustaining and institutionalizing changes over an extended period of time.

Finally, our experience with the teachers in this project has encouraged us to second-guess some sacrosanct ideas in the reform movement. We have no conclusions with respect to this matter yet; we are continuing to explore this question. At this point, we simply offer a caution: Science and math teachers' reticence to embrace reformers' solutions should not automatically be assumed to be a problem; and teachers' ideas about reform should not automatically be dismissed, even if they conflict with reformers' conventional wisdom.

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1. The School Change Study is a 3-year study designed to document whole school change as it occurs in schools that have made a significant commitment over time to CES's principles. Researchers are following 150 students through high school and into college to determine whether students' experiences are different in changing schools. Researchers shadow students in classrooms and interview students, parents, teachers, and administrators as well as officials at the state level. The School Change Study is funded by a grant from the DeWitt Wallace Reader's Digest Foundation, the Exxon Educational Foundation, and the Pew Charitable Trust.

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Natalie A. Hiller

The Battle to Reform Science Education: Notes From the Trenches

DEFINED AS THE ABILITY "to fortify, to surround, to use in battle to protect soldiers from enemy fire" (*Webster's*, 1972, p. 790), the term *trenches* forms vivid images in my mind. As I reflect on that picture, my representation as a soldier or as one in combat is unsettling. Rather than an atmosphere of learning, growth, and caring relationships, it weaves a portrait of fear, anxiety, and strife. When did I become a soldier on the battlefront and who is the enemy? From what am I protecting my students? Is this truly what I carry in my head as I journey through this place called school that I share with so many others dedicated to challenging and motivating the next generation to a new world of scientific literacy? War zones do not instill confidence either in the people who inhabit them or in the future to which they seem irrevocably removed. But perhaps this reality is closer to the truth than I am willing to admit.

"Why Do You Teach Like You Do?"

I sit across the table from a young, dynamic woman, my student teacher for the year, and listen to her questions. She is filled with enthusiasm and hope for the future. Her curiosity seems boundless as she attempts to soak in her new environment for the school year. Tell me everything, her voice seems to say as she proceeds through her litany of chosen questions. I smile inwardly, for the question appears to foster a relatively straightforward interpretation and response. I reflect on my past 5 years as a teacher. The transition has been both exhilarating and exhausting. But now, fearful that a precarious juncture for educational reform and change has developed, I question my own resolve. Consequently, her questions command neither a simplistic nor an easily defined answer.

The discontent with my teaching practice had surfaced slowly and would eventually erupt into full-blown rebellion. Time passed, but questions persisted. The more I looked for answers, the more troubling and numerous the questions became. As a science teacher, I had been acutely aware of the need to make my subject relevant for my students and current in its focus, while at the same time creating a scientifically literate generation for the 21st century. Formulated as a top priority through many national reform efforts (Rutherford & Ahlgren, 1989), these goals had been in the forefront of the science education agenda. However, a national call to arms was not necessary to signal the need to change what was happening within my own classroom.

Observing my students and their world intensified the desire to embrace Freire's (1981) pedagogy in my own practice. His concept that knowing is based on the principle that we all make sense through our own experiences was glaringly absent as I watched my students' distant, disengaged faces and

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their struggle to make sense of science in a foreign, and seemingly hostile, environment. My initial assumption that I could continue to teach in the manner I had been taught became more and more removed from probability as I studied my students. They reminded me of the large gaps that existed between what I wanted for them and the reality of what was.

Maintaining the traditional lectures and chapter-by-chapter coverage, unconnected to meaning in my students' lives, sapped the richness and energy needed to ensure the depth I hoped to achieve. If "making meaning" needed to happen for learning, we were in a desert of knowledge (Berthoff, 1986). I was doing what made sense to me, but was I allowing my students the same privilege? Boredom, accompanied by little desire to become active participants in their educational process, was the order of the day.

My ideas about what I wanted to teach conflicted with the expectations of the district, my department, and other teachers. Uneasiness with the push to cover material as quickly as possible, adherence to a regimented schedule without addressing the concern that learning was or was not actually taking place, heightened my frustrations. To complicate matters, accompanying the effort to cover it "all" was a system of assessment that did not accurately capture my students' growth and progress. Commonly accepted forms of true-or-false quizzes, multiple-choice tests, routine lab reports, and research papers were insufficient to record the daily struggle to teach and learn.

The science teacher within held on to my subject matter with great delight. I have protected, preserved, and defended its content without reservation. But now, this sacred territory of chemical formulas, equations, and molar concentrations was being attacked by those to whom I believed I had the greatest obligation—my students. I needed to know if "real" thinking was occurring or if memorization of facts, without understanding, was the driving force behind the daily rush to teach it all? This quest for a classroom truer to active learning forced me to acknowledge the need to change my comfortable methods of instruction, curriculum, and assessment.

A Philosophical Shift

"Practices that promote conceptual understanding require changes that are far from marginal," Elmore (1992) writes. The statement conveys the massive upheaval I initiated in my teaching practice. Elmore enumerates four problem areas targeted for attention in any school dedicated to the idea of educational restructuring: student grouping, allocation of time for the content subjects, assessment, and teacher division of labor. His list corresponds to the complicated and far-reaching changes I began. However, my reincarnation as a teacher would not be limited to these four, and eventually nothing was to remain untouched.

Teacher research entered my professional world. The process of "active construction" and "inducing conceptual change" (Brophy, 1992) assumed an important role in this transition. I pushed to make my students' life experiences a part of their learning and watched as they struggled to make the necessary connections to these experiences inside the classroom.

My first attempts at change were exhausting, difficult, and without a sense of accepted tradition. Slowly, a philosophical shift took shape from teacher as lecturer and dispenser of knowledge, facts, and information to teacher as facilitator, guide, and coach. Teaching was gradually becoming more student centered as I moved off center stage. I became quieter, and the students began to talk and lead the conversations. They created the questions to study and the directions to explore.

Throughout the process, persistent uneasiness and determined resistance were present. Both my students and I were accustomed to lectures, note taking, memorization, and regurgitation. If I did not give them the correct answers, I was accused of not teaching, not doing my job. Many heated exchanges occurred as I pushed them toward a different experience. "Why don't you just tell us the answer?" became a battle cry. Gradually, however, they became acclimated to my attacks of chemistry "amnesia" as they learned to depend on themselves and each other in this process. If I was going to interpret interpretations, so were they (Berthoff, 1981).

Cooperative groups emerged. Projects that extended over longer periods of time were developed. In my chemistry class, writing that was not the usual lab report or formal research paper tentatively found a place in my "portfolio" of teaching practices. Poems created the images and described the properties of elements while comic strips traced the impact of elements on students' daily lives. Students took on

the role of electrons and wrote letters to the teacher to share this experience. A few years earlier, these demonstrations of learning would have been totally foreign in my classroom.

It was not easy letting go of the comfortable. Many times the unfamiliarity of this new approach created anxiety levels severe enough to cause me to reconsider. But I trusted my students' voices and listened to what they began to say and demonstrate to me in significant and varied ways. The evolution had begun. They were becoming the active participants and the inquirers, willing to dig deeper into the content and the connections to their world.

Bolstered by this unknowing encouragement, which indicated to me increased movement toward greater learning and understanding, I persevered. Their complaints and laments—"I learned more about the periodic table then I ever wanted to. . . . If you would just let me memorize . . . . Why do I have to understand why?"—prompted increasingly bolder approaches to teaching. I read their stories about "The Noble Kings" and their inability to react with the other subjects in the periodic kingdom. I listened with fascination to the gory details of Freddie Krypton and his "Nightmare on Element Street."

I was working twice as hard, but having twice the fun as I allowed their voices to be involved in classroom choices. I was endlessly amazed at the creative ways they exhibited what they had learned. Their first reaction—"This isn't English class."—eventually gave way to acceptance. Books were becoming resources, not the chapter-by-chapter masters of what I was to cover. Less attention was paid to "getting it all taught," and more focus on understanding had begun to emerge. If nothing else, my classroom was hopping with activity.

First tentative steps toward change within the classroom were now established. At the same time, the need to share these experiences with colleagues was growing. Support beyond my classroom was limited if nonexistent in the science department, yet what was happening within my classroom kept pushing me to continue. Many times conversations existed only between the walls and me because of the lack of response from other teachers. Feelings of isolation were growing as the attempt to engage in discussions with my colleagues seemed to drift toward the inevitable same end. I became very familiar with the responses: Tampering with tried and true methods or eliminating parts of the curriculum could be hazardous to the students' welfare. "Would SAT scores suffer? Will the students get into the college they choose? If it's not broken, why fix it? Will this water down the curriculum?"

The last question was a favorite argument for those who resisted change. Any perceived alteration appears to carry with it an automatic assumption that the curriculum must be growing soft. I cannot help but wonder why the reality of the opposite happening seems so remote. Is it because it carries with it the acknowledgment that all is not as it should be?

Change is extraordinarily difficult and uncomfortable. Unless the cost of not changing becomes higher than maintaining the status quo, change is relegated to a distant place within one's daily teaching life. Satisfaction with our performance can lead to a complacency and the incorrect assumption that all is well unless we are willing to look beyond the superficial layer of our students' interactions with us and determine if we have created an arena for true learning.

I believe teachers have a responsibility to bring to their practice a strong reflective process embedded in questions they generate from work in their own classroom. This research should emanate from observations, as well as interpreting what we observe, and then "interpreting our interpretations" (Berthoff, 1981). Fortunately two opportunities appeared with the potential for collaboration with other teachers on a wider scale.

Gaining Support

The first dynamic to materialize was a district call to restructure and reorganize the comprehensive high schools, supported by a Pew Foundation grant. When the request for proposals of instructional units, called charters, was sent out, I formed an alliance with two other colleagues and together we created "Crossroads," a school within a school of approximately 330 heterogeneously grouped students. The goal: Enable students to become lifelong learners and turn the organization of school as we knew it upside down. My ignorance as to the scope and the enormity of this project helped create the illusion of feasibility and hope necessary to jump into the world of restructuring on such a grand scale. If I could not get support within the science department, I was willing to go elsewhere where conversations were occurring

that mirrored my questioning and journey toward change.

My individual attempt to change classroom instruction was now supported by a group of teachers who shared a common educational philosophy. For our program, it was structured around the Coalition of Essential Schools model (Sizer, 1984). What a difference to know that as students passed from one class to another, the expected norm was learning and thinking, creatively and critically. The desire to have students participate actively in their learning process was something to be pursued on a daily basis. Connections among the disciplines were the aspired standard. The years of isolation began to melt further into the distance and I no longer felt as disconnected and alienated from colleagues as I had just a few short years earlier.

The opportunity to have students pursue long-term projects was no longer viewed as an arbitrary solution to an alternative instructional method. A schedule was created charter-wide to enhance this process. Classes were offered for double time blocks to foster this type of work. This alteration dramatically changed how I could teach my classes. New concepts could be introduced and an entire lesson completed because of the longer periods of time teacher and students shared at each meeting. The frustration at having the dismissal bell interrupt a lesson became greatly diminished. The more I became acclimated to this schedule, the more I realized I would now consider the loss of this extended period of time to be sufficient cause to terminate my career as a teacher. An extreme resolution, but it underscores the importance of reexamining the idea of what is untouchable during a school day. It also discards the notion that instructional blocks must be regimented in ways that reflect old habits without regard to their desirability or validity.

Long lectures and passive interaction by the students were welcome casualties of this redesigned roster. Benefits such as reduced start-up times, minimal transition time from one class to another, and sustained concentration augmented a more intense process of learning. New ways to access information developed as the students relied on their peers, their community, and their school as resources above and beyond the classroom. Questions to explore were ones *they* created and grew out of the study that evolved through *their* project.

Since students remain with the same teachers over the life of their high school career, I constructed curriculum with a broader view, across the science content areas. This extra time to immerse students in a deeper and more reflective manner allowed connections and demonstrations of a world contrary to the tidy packages with distinct boundaries known as separate science disciplines. The ease of interacting with my students the second year eliminated time to acclimate ourselves to each other's personalities and classroom techniques. Outside of a few new students, we know one another well with an established history. Strengths, weaknesses, and places for expanded support are set. A portfolio of last year's work is available and we begin as if summer vacation never happened. Work on an intense level is immediate. The familiarity allows a fluidity to their process of continuing an education. So while fear that the attempt to adhere to the "less is more" axiom (Sizer, 1984) can sometimes appear to result in loss of content coverage, I have actually gained, through restructuring and rethinking the school day, new ways to extend interaction time with students that is directly related to my specific subjects.

Other concerns arose. In the realm of choice, who decided which students took courses such as chemistry or physics? Were opportunities available to select certain subjects for all students or was the decision removed from their domain by the "track" they were assigned to years before such a decision became important or relevant. The expectation and requirement that *all* students in Crossroads take subjects such as chemistry and physics, not only those who were deemed qualified because of their placement, partially addressed these problems. In terms of enhancement of science education, the number of physics classes alone tripled within our school by that simple stipulation. Difficulties and struggles are endless but it has been exhilarating and exciting and without a doubt worth every minute, thoughts nonexistent during my years of isolation.

Demonstrations of what is learned and the corresponding process have become as important as reaching a correct answer. Images of teacher roles and responsibilities have undergone a dramatic evolution. Already stretched as a science teacher, I assumed the role as mentor to senior students as they prepared for graduation exhibitions. Complacency and the comfortable mold of science teacher collapsed as

I expanded the knowledge of subjects other than my own.

When necessary, I became the disciplinarian, translated as someone who knows her students well and intercedes on their behalf when situations could easily escalate in negative ways. Budgets, staff development, team meetings crept into my expanding educational world. Charter regulation and maintenance, interaction with local, state, and national school administration, broadened my definition of teacher responsibilities. But in many ways, the revolutionizing of teachers' work has just begun. To "retain able and experienced teachers, we must find new ways to sustain their commitment to working in schools" (Lortie, 1986). Within the charter, I rediscovered that commitment.

Further Connections

The second educational opportunity surfaced at a time when an old source of discontent was growing. Although pleased at the connections blossoming at the charter level, I felt removed from other science teachers and the reforms touted as important curriculum change. National agendas, such Project 2061, Scope Sequence and Co-ordination, were not touching my daily life. I knew about them, had worked on some, and then, like my students' reactions to science, dismissed them. Good people were trying to create a new world of science literacy but they were not viable options in my teaching life because they were not grounded in any relevancy for my students and me. Our voices were silent in this process, as my students' voices used to be silent in my classroom. Connections and conversations were not happening to sustain enough interest on my part. I was searching now, not later. I was frustrated. If these were to be the national guidelines for science education into the next century, when would it reach my world and make a difference? Waiting for some useful input or information proved fruitless, and so once again I started off in other directions.

A ray of hope emerged from an unexpected source. The Coalition of Essential Schools, headed by Ted Sizer at Brown University, was conducting a study of school change. My charter was one of the five participating schools located across the country. After the first year, it was expanded through funding by the National Center for Science Teaching and Learning to include a focus group of math and science teachers specifically from these schools. Our discourse was to reflect some intense dialogue about change in our teaching practices. This dubious honor was bestowed because the image math and science teachers had earned was one of inflexibility and difficulty in accommodating the changes that humanities people seemed so willing to embrace.

As a result, on a cold day in January, I found myself sitting in a room with math and science teachers from across the country. So began one of the most exciting weeks in my teaching career. Those same questions about instruction, curriculum, and assessment that I asked were now raised by others. Nothing was too sacred to be examined. Ideas flowed at a steady pace, and conversations lasted for hours. What a luxury—to be able to share with other math and science teachers in such a supportive environment.

Collaboration with these energetic teachers has continued over a sustained period of time. It has resulted in teacher-research projects in our classrooms, new curriculum, and the subsequent piloting of our work. We have become colleagues unhampered by the arbitrary boundaries of a classroom.

Out of the Trenches

What was similar between what I had experienced within the charter and within the math and science change study? Why did they become important to my work as a teacher when other local and national initiatives failed to create a connection to my classroom? For me, the answer lay in the expression of the teachers' voices, loud and strong, through the creation of collaborative work. It was driven by those who knew their world best and, as a result, took on a dimension denied to those who participate in it as outsiders. Teachers *know* but are seldom asked. Others assume they can do better and then impose. In education we do not learn our lessons well.

The change process that swirls around my teaching life has arrived at a place framed by pain and apprehension. I willingly embrace the task of creating communities of learners in ways very different from my personal learning and previous teaching experiences. I also realize the avoidance of pain is impossible if reform is to continue. I am discouraged when one of the most vocal enemies of my work with the charter is the teacher's union that supposedly protects and defends the rights of teachers as they advance the cause of educational reform. I become

cynical when administrators, far removed from classroom interaction, make decisions to undo the fragile structures of reform.

I cling stubbornly to the knowledge that the reward resides in the exhilaration of both teachers and students who are aware of what can be. For me, this is sufficient to keep the process on its rocky, uncharted course (Sizer, 1984). Ongoing transitions occur to shape who I am and what I will become as a teacher. And so within this framework, bounded on one side by hope and desire and the other by what appears to be insurmountable roadblocks, I persevere.

To deny this moment of opportunity in education will affect not only the struggling reform within science education, but would impact the lives of our students who deserve to experience learning that is real and valuable. It cannot occur in a vacuum or unsupported by those who control the policies and structures necessary to move forward. Power issues, maintaining status quo, and the fight against change in roles and responsibilities for all parties involved cloud and stagnate the difficult conversations required for reform. The voices so desperately needed in this battle must not be silenced. Consequently, rather than remain in the trenches, I have chosen to lead the charge.

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Juanita Garcia Wagstaff

Site-Based Management, Shared Decision Making, and Science and Mathematics Education: A Tale of Two Districts

ALTHOUGH MANY REFORM INITIATIVES have the potential to influence science and mathematics education, they do not all specifically target these areas of the curriculum or curriculum issues in general. Site-based management (SBM) and shared decision making (SDM), for instance, are school restructuring strategies designed to decentralize the control of schools (Conway, 1984). These strategies are based on the assumption that school-level staff, working collaboratively, are in the best position to make appropriate decisions for their particular sites. Some SBM models also assume active involvement of parents and community leaders in the decision-making process.

It is generally agreed that the overriding aim of the restructuring movement and SBM and SDM in particular should be improved student achievement and that the greatest potential for increased student learning lies in changing curriculum and instruction, the core technologies of schools (Elmore, 1990; Fullan, 1991; Sarason, 1990). There is also speculation—and an increasing amount of empirical evidence in the literature—which suggests that, while SBM may result in some minor changes to governance structures, it has not had much of an impact on the academic culture of schools or on improving instruction (Clune & White, 1987; Fullan & Miles, 1992; Malen, Ogawa, & Kranz, 1990; Raywid, 1990).

This article examines the potential for SBM and SDM to impact the curriculum in general and science and mathematics teaching and learning in particular. Unlike much of the research to date, the focus of the research that supports this article is not on what is typical; rather the focus is on what is possible and the conditions that will make the possible more probable.

Source of Ideas

The ideas presented here have been gleaned from in-depth case studies of SBM and SDM in two school districts that have experimented with both strategies over a period of years. The two case studies are a component of a larger study that looked at various aspects of school restructuring in reputedly successful school districts in Texas, Florida, Kentucky, and Colorado (Wagstaff & Reyes, 1993). A study team comprised of four professors and three graduate students visited the study sites over a 6-month period. A sample of 16 schools was selected in each district. Semi-structured interviews lasting approximately 45 minutes to 1 hour were conducted with SBM participants, which included key central office administrators, school board members, principals, teachers, and parents. In the case of the two districts discussed here, interview data from the larger study were supplemented with data collected during

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additional interviews conducted for the purposes of member checking (Lincoln & Guba, 1984) and responding to questions generated by preliminary data analysis.

The two school districts were identified by state department of education officials and other experts in the state as being involved with some version of SBM and SDM. Both sites are located in Texas, which in 1991 passed a law (House Bill 2885) mandating that each school establish a local campus committee to work with the principal in goal setting, curriculum, budgeting, staffing patterns, and school organization. This bill extended a law passed in 1990 (Senate Bill I), which gave primary authority to building principals (after consultation with faculty about desired qualifications) for campus appointments as well as the right to request waivers from laws and state rules that impede their success with students. Both of the sites discussed in this article, however, had experience with site-based management prior to being required legally to do so.

District A, in fact, had a history of school reform initiatives. These initiatives were, at least in part, a response to the district's changing demographics. In the 1970s this wealthy and conservative, semi-urban district had a student population that was predominantly White, with only 15 percent minority, and 1 percent low income. By the early 1990s, however, the student population had shifted dramatically to include 50 percent White, 32 percent Hispanic, 10 percent Black, and 8 percent Asian, with 40 percent of the students on free lunch.

In 1986-87 the district, as part of its effective schools program, established a campus improvement team (CIT), composed of parents, teachers, and administrators on each campus. The primary purpose of the teams was to review and study school-based data and develop a campus improvement plan. Although CITs were instrumental in developing improvement plans, which were a key component of the effective school process, they were unable to monitor and adjust the school's efforts toward improvement on an ongoing basis.

Thus in 1989 the district decided to implement site-based management, and a new organizational entity was established—campus leadership teams (CLT) made up of 6 to 7 teachers and the principal. The expectation was that CLTs would work to implement, on a day-to-day basis, the more general vision adopted by the CITs, the group that also included parents.

In the first year of implementation, the principal selected the teachers to be on the CLT or asked for volunteers. In the last 3 years, however, teachers have been elected to the CLT by their peers. Any teacher can attend the CLT meetings and give input, but only elected teachers can vote. Department chairs and district instruction coordinators serve as ex-officio members.

Most of the CLTs meet weekly, but in some of the district's secondary schools, they meet more frequently (often daily) to govern and lead the school improvement efforts. In principle, these efforts are consistent with and reflect the contents of the campus improvement plan developed by the CIT, the group that includes parents. In practice, the relationship between CLT's efforts and the CIT's plan is not always clear.

District B, located in a large urban county in the western section of the state, has a rapidly growing student population. Eighty-nine percent of the students are Hispanic, and 70 percent are classified as economically disadvantaged. District B is described as a property poor school district (many students live in "the colonias"—subdivisions characterized by third world living conditions, lacking water or sewage systems).

District B, like district A, had experimented with SBM and SDM for several years before it was required by law to do so. As in District A, the restructured decision making utilized committees that worked at different levels in the district. A district-wide committee, the Educators' Professional Advisory Council, was chaired by the superintendent and composed of parents, teachers, principals, and other central office staff. Teachers serving on this district- wide structure were local representatives elected by their peers. A school improvement team (SIT) also was present at the school site. This committee included elected teachers, parents, community members, and students at the secondary level. The SITs meet on a regular basis (at least 2 or 3 times a month) to develop budgets, plan instructional improvements and staff development, and select personnel.

The discussion now turns to a consideration of what was learned when we examined SBM and SDM in the two districts described above. The discussion of this general question will be organized around three more specific questions:

1. What impact, if any, did SBM have on curriculum and instruction generally and the teaching of science and mathematics in particular?
2. If there is evidence of impact, what conditions help account for this atypical (according to the literature) occurrence?
3. What are the apparent costs and "value-added" of SBM and SDM in these two districts?

Impact on Curriculum and Instruction

The data suggest, in both districts, that SBM and SDM had a significant impact on curriculum and instruction. The field of mathematics received considerable attention; less activity was directed toward science.

District A

In district A, the impact came in three distinct areas: (a) heterogeneous grouping of students for purposes of instruction, (b) integrating curriculum content, and (c) scheduling for improved instructional opportunities. With respect to the first point, for instance, decision-making groups in five of the district's schools eliminated remedial and honors classes and were grouping students heterogeneously in core subject areas including math and English. SBM groups in other schools in the district were also discussing taking similar actions.

The move from homogeneous to heterogeneous grouping has not occurred without some degree of controversy. One of the most controversial incidents in the district concerned one high school CLT's decision to eliminate ninth grade math and English remedial and honors classes after it had piloted heterogeneous grouping in math classes during the previous year. Later that year, the CLT had to reverse its decision to heterogeneously group students in the English classes due to parental and community pressure.

Five of the schools studied also had begun the process of integrating the curriculum content in the various subject areas. At one of the elementary schools, for example, substitute teachers were provided so that grade-level teachers could meet with the principal off-campus to plan and develop thematic units that blended major content areas such as English, math, science, and social studies. Higher order thinking skills were emphasized in many of the units. In one school, in particular, science and social studies content served as the focal point for these integration efforts.

Finally, three of the schools organized the instructional day to accommodate larger blocks of time for major subject areas. For example, the CLT at one of the middle schools decided to eliminate most of the elective classes in order to provide students with 90-minute blocks of language arts and math. One of the teachers interviewed said:

> We don't have to depend on the [administration] building telling us what to do. We're able to say well here's where we need to get down to the basics and so we double blocked in math in sixth grade. We're doing it next year in seventh grade and they double block language arts at all three grade levels . . . so we're looking to see what do our kids need, not necessarily what do other kids at other schools need and going from that. Just looking at our test scores, looking at just ours, and not comparing them to anybody else, and giving what our kids need.

Flexibility in scheduling involved teachers' as well as students' learning time. At one of the elementary schools, the CLT scheduled a weekly early-release day so that teachers could participate in inter-grade level planning. Other schools altered the school day in order to provide weekly staff development.

Other curriculum and instruction related initiatives made by the CLTs included the establishment of mentor teams, the creation of a task force to evaluate the English as a second language (ESL) program, the implementation of a Spanish general equivalency diploma (GED) prep program, and writing a proposal to teach algebra and English in a lab setting.

District B

Data from District B also suggest that SBM and SDM had a significant impact on curriculum and instruction in general and science and mathematics teaching in particular. In District B, the impact came in four distinct areas: (a) grouping of students for the purposes of instruction, (b) scheduling for purposes of instruction, (c) teaching for understanding instead of "lecturing or telling," and (d) integrating curriculum content.

With reference to the first area—grouping students for the purposes of instruction—for example, seven of the elementary and four of the middle school SBM groups had established heterogeneous classes of limited English proficient (LEP) and non-LEP students. These classes emphasized team teaching, higher order thinking skills, and cooperative learning strategies.

At four of the elementary schools and two of the middle schools, SBM groups had also established

multigrade/cross-grade level reading, math, and writing labs. The principal at one of the elementary schools emphasized that it was the teachers who

> took it upon themselves and they set up some rearranging of programs and now we have a reading lab and a math lab and a writing lab in the mornings, and children are sent to the different labs depending on what their needs are. It is a conglomeration of fourth, fifth, and sixth graders in one particular classroom doing math or writing or reading.

Second, the SBM group at one of the high schools had blocked the major content areas into four classes instead of seven classes for at-risk students. Students, in other words, had fewer subjects for longer periods of time each day, and consequently they completed year-long courses in half a year. In describing the process, one of the high school teachers stated:

> We also have a block system for at-risk students. This was implemented because we saw the need to keep these kids in school, and to show them that they can succeed. Part of the problem was that they were taking seven classes, so the suggestion was made to block the students into 2-hour blocks of classes, so they would take four classes at a time. The success rate went way up. We are even considering doing that with the regular student body. If they have less to think about they can concentrate more on what they are doing. These are the kinds of ideas that teachers come up with that might never be tried if it were left to an administrator.

Third, the SBM group in another high school decided they were not doing an effective job of teaching their students to think and they wanted to get away from "lecturing and just giving information to students." They embarked on an intensive staff development program that emphasized problem solving, higher order thinking skills, and critical analysis. One of the SIT members recalled the process of finding the money for the staff development program: "We did it by shifting our funds around and having to say, okay, we are going to not do this or that because we don't have the money. . . . We thought that was good."

According to the assistant superintendent of curriculum and instruction, "The actions of this particular SIT caught on like wildfire in the district." Other SBM groups in the district began looking critically at their teaching practices and implemented staff development programs that would help the teachers include more problem solving, higher order thinking skills, and critical analysis in their teaching strategies. Finally, as in District A, several of the schools in District B had begun the process of integrating the curriculum by developing thematic units that blended major content areas such as English, math, science, and social studies.

An Atypical Response

The evidence clearly suggests that SBM did indeed have an impact on curriculum and instruction in these two districts. The impact on math was relatively significant. SBM teams focused less often on science. There were undoubtedly many reasons for this disparity, but certainly one reason was that the state assessment, at the time of this study, focused on math and language and did not include science. Particularly in District B, the majority of improvement efforts related to curriculum and instruction were geared toward improving students' scores on the state test. This is not surprising since a school's scores were published in the newspaper.

Determining whether the impact observed was positive or negative was beyond the scope of this study. Undoubtedly most reformers in the field of science and math and reformers generally would applaud many of the changes made—in particular, the diminishing of tracking, the integrating of curriculum content, and the focus on higher order thinking and more active and cooperative learning. Most of these ideas, for instance, are endorsed in Chapter 13 ("Effective Learning and Teaching") of *Science for All Americans* (Rutherford & Ahlgren, 1990). Advocates for science education, on the other hand, might be concerned that the increased emphasis on language and math in some schools could have resulted in a diminished emphasis on science. At the very least, they would be disappointed that most SBM teams did not pay more attention to science.

Still, independent of whether the impact of SBM on curriculum and instruction was positive or negative, the very fact that some significant impact occurred is, in and of itself, unusual. The discussion now turns to an analysis of this atypical situation. Why did this happen? Why was there an impact when the empirical and theoretical literature predicts little or no impact? What particular conditions help explain the atypical response in these two settings?

Accounting for the Impact

Our analysis suggests several factors that may account for the atypical impact of SBM and SDM on

curriculum and instruction in these two districts. The first factor is historical, i.e., it involves things that happened prior to the implementation of SBM and SDM.

Norms established in advance

In both districts, the foundation was set for decentralization via training and the establishment of important norms prior to the implementation of SBM. In District A, this was done primarily through the effective schools process, which emphasizes both campus-based strategic planning and focusing the planning process on curriculum and instruction.

The latter emphasis, for example, helped establish norms and patterns of behavior related to focusing on curriculum and instruction within the district—a district culture, to use contemporary nomenclature—long before SBM and SDM were introduced. It should not be surprising, therefore, that those who participated in SBM and SDM continued to act out established cultural patterns, just as it should not be surprising that teams in districts that have traditionally underplayed the significance of curriculum and instruction continue to do this once decision making becomes school based.

The effective schools movement also helped establish the norm of planning at the building level. Although planning in the effective schools process was more highly structured and required more assertive principal leadership than is required when decision making is truly shared, the effective schools initiative helped establish new norms about where decisions were made in the district and provided an arena for developing and practicing skills required for making decisions at the building level. To be sure, both districts provided intensive training programs in group process skills and leadership training to both teachers and administrators, particularly to the SBM team members, and this formal training is a significant part of the story of the two districts' success. Still, it is significant that many skills needed for SBM and SDM already had been acquired informally prior to instituting more formal training.

Intentional incrementalism

Implicit in what has been said is a second significant factor that needs to be made explicit: Both districts believed that SBM should be implemented incrementally. In the words of one of the district's superintendents, they used the "go slow approach."

District B, for example, began its restructuring efforts in 1988 by decentralizing its budgeting process. Initially, the SBM teams were given little discretion and they dealt primarily with such budgetary issues as supply accounts and modest equipment line items. Progressively, the teams have been given greater latitude and flexibility and are now responsible for a broader array of accounts.

Support from the top

Both districts took steps to institutionalize SBM by providing adequate resources, ongoing training, technical support, and clear district-wide parameters about the types of decisions the SBM teams could make. Both superintendents felt strongly that the role of central office administrators was to support and assist individual school sites in making sound decisions. In fact, District A's superintendent said:

> I will review at the end of the year how many times central office staff have been contacted by teachers to provide services. If any central office staff have not been contacted then I'll conclude that such jobs are not important and thus not needed.

Superintendents also established other mechanisms to insure that SDM was not simply procedural display. In one district, for instance, teachers had to sign completed budgets to indicate that they had been part of the budgetary process. Both superintendents provided interpersonal as well as structural support. Both superintendents, for instance, continued to meet on a regular basis with groups of teachers to discuss problems and barriers to SBM even after the innovation was well established.

Both districts also took steps to insure that the SBM teams focused on "topics relevant to instruction" and instructional improvements that would increase student learning and achievement by providing strong district-wide instructional guidance to the schools and other forms of control. For example, the superintendent in District B initially required that the minutes of every SBM team meeting be sent to his office in order to insure not only that the teachers were "true participants" in the decision-making process but also that the meetings focused on instruction.

There is a certain irony in superintendents using their positional power in the organizational hierarchy to force people to make their organizations less hierarchical. One is reminded of Rousseau's (1762/1968)

ideas about forcing people to be free (p. 64). This paradox, however, seems to be a significant component of making SBM and SDM work. Top-down direction may be particularly important in districts where the importance of focusing on curriculum and instruction is not well established and where teachers and principals have not had an opportunity to develop the necessary skills informally. In such places, superintendents may have to articulate a new vision and insure that adequate resources get targeted for SBM and SDM skill training.

Pressure from the state—and a caveat

Although the focus here has been on what happened *within* the district, one other form of top-down control is part of these two districts' stories and must at least be acknowledged before proceeding. In addition to pressure from the district to focus on curriculum and instruction, pressure to do this also came from the state—in the form of a high-stakes assessment system. The publication of student scores on these high-stakes tests certainly got SBM teams' attention and undoubtedly helped team members focus their collective attention on changing curriculum and instruction so scores would improve. As was noted above, SBM teams' relatively strong emphasis on math as well as language and their somewhat limited attention to science is at least in part attributable to the fact that there were state tests in math and language, but none in science.

For many science education reformers who want to see more student-centered, inquiry-oriented, and real world approaches to teaching science in the nation's schools and classrooms, this particular finding poses a vexing dilemma. Tests traditionally have driven teaching in decidedly different directions; one wonders, for instance, whether the school that built integrated thematics units around science and social studies concepts would have felt free to do this if there had been state tests in science and social studies and if students' scores on these tests would have been made public. At the same time, the schools' focus on science was the exception rather than the rule; most SBM teams tended to ignore science despite their general concern for curriculum and instruction. Such behavior on the part of SBM teams would have been less likely had there been a high-stakes test in the science area.

A more authentic assessment system may provide a way out of this dilemma. Articles by Page and Donmoyer (this issue), however, suggest that a standardized authentic assessment system may be more a problem than a panacea.

Costs and Benefits

Although a formal cost-benefit analysis was beyond the scope of this study, it seems important to at least consider the matter of costs and benefits informally. To the extent that teacher time is limited and involvement in governance is time consuming, it may well be the case that SBM and SDM have a negative impact on curriculum and instruction even if teams deal with curriculum and instruction. To the extent that we are playing a zero sum game, in other words, involvement in governance may interfere, in significant ways, with teaching. Here we report what people in the district said about questions of costs and benefits.

Teachers were certainly aware of the costs of site-based management and some complained about being "stressed out and overwhelmed" by the demands this reform placed on them. One teacher, for instance, stated:

> You cannot go out there after school, after a full day's work, and still be energetic enough for another 2 hours or so [to attend SBM meetings], and not say, I don't have an outside life. We are postponing our lives outside to fulfill a commitment. What you see is necessary, but it is infringing.

The central administrative staff in both districts were also concerned about how long the teachers and administrators could sustain the high levels of energy and commitment that SBM demands. District A, in fact, built-in time during the school day for most of the SBM meetings and has provided a monetary stipend to CIT teacher members for the last 2 years, but at least one teacher indicated that additional money could not really compensate for the added toll. "Even if you are getting compensated," the teacher told us, "there comes a time when you have to say that you just want one job, not two. I have a wife and a kid, and my wife has an extra job for me at home."

These views, however, represent the minority point of view. The vast majority of teachers and administrators interviewed acknowledged the high costs of SBM and SDM but felt the costs were more than worth paying. Their comments suggest that what

we have here may not really be a zero sum game at all, that the time invested in SBM may have positive spillovers into areas other than the specific policy questions addressed.

The majority of teachers in both districts, in fact, reported increased levels of motivation, commitment, and satisfaction as a result of being, either directly or through a representative, part of the site-based, decision making process. One of the faculty interviewed said:

> This is a place I want to work in . . . the kids, the programs that we have here, the freedom that I have. It makes me nervous sometimes thinking about going someplace else and being told you will not use the science labs, and you will use the textbook. It is very nice. I come to work in the morning and I feel good because I know that what I'm going to do is going to work. I know nobody is going to say you can't do that, unless it is something very dangerous or very extreme.

The most cited benefit of SBM by both teachers and administrators was the opportunity to meet the needs of the different groups of students, particularly at-risk students, in unique and creative ways. A principal describing the different attitude of students and faculty said:

> I think that our kids have really been more focused this year and our teachers have really been able to work with them and feel like they could do things differently or unconventionally than they normally would because they are feeling this is our campus, these are our kids, and we're going to try different ways to help them that may be different than someone else has. . . . We didn't feel pressured to do things a certain way because someone else is doing it. We felt like whatever we needed to do for our kids, then that's what we would work towards. And I think that's been the message to the teachers and to the kids. And I think it's been a very strong one, because just the whole attitude, you know, like you might get an idea and you don't think twice about it not being accepted. If it's good and it's going to benefit the kids, then it's usually like, go ahead and do it. Let's see what happens.

In addition, many of the teachers reported a sense of direction and awareness that they had not had prior to SBM. Others reported a renewed sense of creativity and enthusiasm about their teaching. For example, a teacher said:

> I think that site-based management really works. And I think that it is very positive. It makes the teachers feel part of the curriculum process. And it actually extends to the students because we often talk to the students about what kinds of classes they would like to have. I think they feel that they have some kind of input. The administration is very open to listening to our ideas.
>
> One example is we just finished writing a National Endowment for the Humanities grant proposal because there is a group of us who want to study the border culture. . . . I called somebody at the university, as it turned out a representative from the National Endowment was going to be there, and they asked me to come, so I asked if I could have a day to go to the university and to go to the meeting. No problem. We put the grant proposal together, and submitted it. We didn't have to submit it to anybody for approval, all we received was just positive support. In the other district, somebody would have had to intervene and give permission.

Finally, the data suggest that many of the teachers were no longer working in isolation but were sharing and collaborating with their colleagues. Many of the teachers talked about "no longer being able to go to your classroom and shut out the world" and about how "much easier it is to work with the philosophy of sharing than it is to try to hide your ideas from your peers." In addition, teachers talked about how their views and attitudes had shifted from "my classroom to my school." One of the teachers stated:

> The attitude toward working in a school has broadened. It used to be my classroom; then we started working with other teachers on grade level and we were concerned about grade level things. Then we thought we need to articulate among the grade levels and talk to the grade levels below and above and see what they're doing and so that was like, great, if you could do that. But now what's happened is that the perspective is the school level and what's good for the school. It's not just my classroom or my kids or my anything. It's how are we as a school achieving and it has really broadened our vision of what's good. And even we'll talk about what's good for the district and that's very nice.

Thus, the most frequently cited cost of SBM was the amount of time it took. Surprisingly, however, the majority of the teachers felt the cost was not too high, particularly when they compared it to the benefits they received. These benefits included a voice in decision making, which, in turn, led to a heightened sense of efficacy—being able to do what is best for kids. This heightened sense of personal efficacy, in turn, helped create a communal environment in which teachers had an opportunity to share ideas and concerns and to discuss their work with other teachers. The words of one teacher were echoed by others within the two districts, "I've never worked harder in my life, but I've never been happier."

Conclusion

Whether the benefits participants perceived are sufficient to sustain this innovation over an extended time period remains to be seen. We are also left with two other important questions: Can what has happened in these districts be duplicated in other districts in which the cultures are less hospitable and the personnel less supportive? To what extent should we use top-down control mechanisms such as statewide, high-stakes testing to encourage SBM teams to focus attention on and build improvement efforts around science?

Both the potential and the problems associated with SBM and SDM are illustrated nicely by an incident alluded to earlier in this article. It was noted that a site-based management team's decision to eliminate tracking—a decision that would be supported by most reformers concerned with science and mathematics education and reformers generally—had to be reversed due to pressure from parents. The irony is that the leader of the group of parents pressuring for reversal acknowledged after the group was successful that reversing the site-based management team's decision was a mistake. The leader said he had not understood the issues and that by the time he understood and altered his stance, the political process had been set in motion to reverse the SBM team's anti-tracking policy.

Had this parent been a member of the team that decided to reverse tracking in the first place, he might have been able to explore the issue of tracking outside of a power-politics context. This district, however, found that it was hard enough to find the time and resources to involve teachers in meaningful ways in decision making; finding ways to involve parents seemed virtually impossible.

The incident suggests we may be on the horns of a dilemma when we confront SBM and SDM. Unless we involve large numbers of people, inside and outside of schools, in the decision-making process, we may not be able to get the sort of support that makes reformers' ideas viable and implementable. On the other hand, the costs of involving large numbers of people, particularly parents and community members, may, unfortunately, be prohibitive.

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Charol Shakeshaft

Reforming Science Education to Include Girls

ANY REFORM THAT ATTEMPTS to increase science literacy must deal with a disturbing truth: Women do not do science. While my position is clearly an exaggeration, since there have been many famous women scientists in the history of the world, recent studies tell us that even among the most academically prepared in science and math, males choose math and science majors and careers in much larger numbers than do females.

One study reports that among seniors who have taken physics and calculus, 64 percent of males and only 18.6 percent of females were planning on majoring in science in college (AAUW, 1992). Arnold (1993) has studied the education and career paths of academically talented women and men and reports that 15 years after graduating as valedictorians of their high schools, women are more likely than men to have moved away from science majors and careers.

During elementary school, males and females are equally interested in science, and as many girls as boys say they are going to be scientists when they grow up. As students reach middle school, the sexes begin to move apart in interest, participation, and achievement in science. By the time they graduate from high school, males express more interest in science and are twice as likely to report they will pursue careers in science (Linn & Hyde, 1989).

In high school, when students are free to select courses, males and females make different decisions. Males are more likely than females to take physics and advanced chemistry, while females are most often found in biology classes. If girls are not required to take science, they often do not (AAUW, 1992). Parents and counselors are much more likely to tell boys to stay in elective science courses than to brief girls on the importance of science to their futures.

Recent state mandates that increase the number of years of science required for high school graduation have also increased female science participation. However, these reforms have had little impact on participation in advanced courses, since few states require completion of advanced physics or chemistry for a high school diploma. Indeed, the more advanced the science course, the fewer females enroll. For instance, a 1990 study by the Council of Chief State School Officers found that 60 percent of first-year and 70 percent of second-year physics students are male (Blank & Dalkilic, 1990).

Gender differences in science also exist in measures of achievement. The National Assessment of Educational Progress notes that gender differences in the science achievement of 9- and 13-year-olds increased between 1978 and 1986. The largest gender differences are for 17-year-olds, and have not changed since 1978. Males are more likely than females to do well in physics, chemistry, earth science, and space science (Mullis & Jenkins, 1988). The Educational Testing Service reports that males score higher than females on AP (advance placement) biology and physics tests, although the differences

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in biology achievement are declining (Mullis & Jenkins, 1988).

Despite receiving grades in science that are as good or better than boys' grades, girls continue to lag behind males in tests of science achievement. Linn and Hyde (1989) have demonstrated that these differences are largely explained by the format of the tests, not the ability of the student. However, some of the gap in the scores can be explained by understanding gender differences in test-taking skills. Boys are more likely to guess and estimate answers. Girls are more likely to work out the exact solution to problems. We need to prepare all students for these tests and teach girls to take risks, estimate answers, and take shortcuts in their problem solving.

In their meta-analysis of the studies that have examined why females and males perform differently in science, Linn and Hyde (1989) conclude that the explanations of difference are contextual and societal, rather than biological. The results of their analysis make clear that schools can close the achievement and participation gap between males and females. From Linn and Hyde we learn that any attempt to reform science curriculum that does not directly deal with societally and contextually imposed gender differences is likely to address only half the problem. This article summarizes some of the gender expectations that exclude girls from science participation and that lower female achievement, as well as suggesting ways schools can counter these barriers.

The Traditional Focus of Science

Boys have more confidence in their ability to do science than do girls. Girls are more likely than boys to see themselves as science outsiders, rather than science insiders (Koch, 1992). Science insiders are confident they will do well in science and find the content of science class familiar territory. Outsiders do not identify as scientists, have little confidence in their abilities, and do not relate to much of the traditional focus in science classes. Several factors combine to help boys be insiders and girls outsiders.

Males come to school with more informal experience in science than do girls. Parents of boys are more likely than parents of girls to buy their sons science toys, send them to science camps or after-school activities, and subscribe to science magazines.

Boys are more familiar with concepts in the physical sciences and are more likely to have worked with the tools and materials commonly found in science labs than are girls. For instance, Linn and Hyde (1989) note that by eleventh grade, "49% of males compared with 17% of females report use of an electricity meter" (p. 22). Boys are more likely to have repaired bicycles, built treehouses, and tinkered with engines than are girls. These out-of-school experiences provide boys with an added advantage for science learning, giving them familiarity with the physical sciences as conventionally taught in schools.

Girls also bring informal science learning to schools, but teachers and students rarely think to label what girls do in stereotypic girl play as "science." Few have helped females conceptualize cooking as experimenting or playing house as social science. When girls analyze human behavior, they are called gossips; when adult males do it, they are called psychiatrists. When girls tell us why they drop out of science, they often explain that science is neither interesting nor useful to them. Schools have not helped girls understand that what they care about is science.

Girls do more science than they realize. Girls use tools all the time, but do not label them as such. From kitchen and garden implements to scissors and hair appliances, girls work with tools. This familiarity with some forms of tools can be used as a way to expand female risk-taking and comfort level with other tools, and help girls understand that the world of science is not as unfamiliar as they might have thought.

Using the informal experiences of females as a bridge to science in the classroom is a necessary step in increasing female participation in science. Naming the play of girls "science" will help girls think of themselves as science insiders and increase their science confidence. Expanding classroom science activities to include what is a familiar part of the world of girls will boost girls' interest in and identification with science. Incorporating teaching strategies such as scaffolding or including problem-solving exercises that will help build science confidence are especially valuable for females (Koch, 1992).

The Stereotype of the Scientist

Koch (1992) writes that as early as second grade, both boys and girls imagine scientists as "white men who have unusual hair, wear glasses and lab

coats, and are involved in some sort of explosion." This stereotype is more a barrier for girls than for boys. In order to see themselves as scientists, girls must first be able to envision a woman as a scientist.

However, it is not simply that girls require female role models, they need a range of female role models. It is critical that girls meet and talk with women who have combined a demanding science career with a satisfying personal life. A recent study illustrates this point.

Arnold's (1993) longitudinal study of female and male valedictorians of high schools illustrates the importance of the dual nature of direct role modeling on the science career choices of females. Arnold discovered that for many females, it is important to have contact with women scientists who combine careers in science with parenthood. While she found few differences in male and female career aspirations among valedictorians when they graduated from high school, 4 years later the aspirations of many of the female students had dropped.

The reason most female students gave for their change in career plans was that they believed they could not combine a demanding science career with the responsibilities of parenthood. College females who had seen women combine motherhood with careers or who were willing to wait until their 30s to have children were more likely to stick with their plans for a career in science. Those who had not seen women scientists who were mothers or who planned on having children in their early- or mid-20s were likely to have lowered their career aspirations.

Arnold's study suggests that if we want to keep girls on the science track, we need to make sure they meet plenty of women scientists who assure them that being a mother and being a scientist are compatible. The more women scientists girls meet and the more they learn about these women's lives at home and at work, the less likely it will be for girls to think that scientists are White men in lab coats.

The Stereotype of the Girl

Although images of strong girls who pick up bugs, play with snakes, and tramp through marshes are more common in the '90s than previously, the stereotype of the girl who screams when she sees a spider is still widely broadcast. Koch (1992) reports that some girls still behave in sex stereotypic ways, even if they do not actually feel the response. A quote from her study illustrates how girl-expected behavior gets in the way of doing science. "I did not mind dissecting a frog in seventh grade though that was not how I reacted. . . . I screamed so that the boys would notice I was acting like a girl."

Koch also points out that helping girls overcome their squeamishness about getting dirty is necessary if we are to engage females in some of the work of science.

> It is the women who do the real "messing about" as they maintain the daily fabric of life. They are messing about with diapers, sicknesses, toilets and the business of birth! . . . The message for teachers is clear—getting messy is one way of knowing the world, so help your students take the icks and yucks out of science!

Helping is Hurting

Girls sometimes get too much help when they are learning science. For instance, in a science lab or experiment, both teachers and boys demonstrate and then complete the activities for girls, while demanding that boys do the work themselves. This intervention with girls, although meant to be helpful, keeps girls from experiencing their learning and makes it a demonstrated, rather than lived, experience. Girls learn that if they sit back and ask for help, someone else will do the experiment for them. Even if they do not want help, girls are often pushed aside and not allowed to finish.

We need to help teachers and peers learn to require girls to do their own work so that we do not make girls "learned helpless" in science. Koch (1992), in her study of women in biology, quotes a high school girl who recognized this pattern:

> My lab partner and I were having trouble locating the paramecium on the slide when our science teacher said, "Come on girls, hurry up; if you can't find it ask the boys behind you."

Still another girl in the Koch study reported that she was the only girl in her AP chemistry class and that her teacher "did my experiments for me." Taking over for girls is an act that not only deprives a girl of a valuable learning experience but also reinforces the notion that she is not very capable.

Male Dominance in the Classroom

Males participate more in all classes than do females. This is true because teachers call upon boys

more than they do girls, and because boys volunteer their thoughts and opinions more than girls. Boys talk more in class, answer more questions, and voice their opinions more often than do girls. Some studies estimate that male participation is eight times more than female, and that this gender imbalance is especially exaggerated in science and math classes (AAUW, 1992).

Teachers are much more likely to allow boys to call out and interrupt, while forcing girls to wait their turn and "be polite." This behavior teaches girls not to answer questions, not to let their enthusiasm spiral, and not to get involved. It also teaches them that they are less important in the classroom.

In order to involve girls in science classroom discussion, teachers must adopt strategies that recognize and confront male dominance and female reticence. A simple, but effective, strategy is to put every student's name on a card and, after shuffling the cards, call on each student as her or his name appears in the pile.

Teacher-Student Interaction Patterns

In addition to a disproportionate amount of teacher time and feedback in science classes, boys receive more positive, reinforcing feedback from teachers than do girls. For instance, boys who are high achieving are told by teachers that they are smart or that they will become scientists. High achieving girls are told they work hard or are lucky (Sadker & Sadker, 1994).

Teachers ask boys more probing questions, force them to stick with the process, and expect more of them. Teachers are much more likely to "let a girl off the hook" if she does not know the answer, while forcing the boy to puzzle through the answer.

These are a few of the subtle differences in teacher-student interaction patterns that have an impact on science achievement for females. Without an understanding of how these behaviors limit girls, reform in science education will improve only for boys.

Teacher Attitudes Toward Science

Teachers' attitudes toward science have an impact on how girls feel about science, and often those attitudes are transmitted in very subtle ways. Observing math-phobic and math-loving women elementary teachers in the classroom, Karp (1988) has documented how attitudes toward math are passed from female teachers to female students. Her work links the feelings of teachers toward math with the attitudes of female students, and has implications for science teaching.

Although Karp did not know which teachers were math phobic or math lovers when she observed them, she found differences between the teaching styles of each. She also found differences in the attitudes of the girls in the classroom. Although all the children—boys and girls alike—believed that all their teachers loved math, the girls in the classrooms of the teachers who really did love math also said it was their favorite subject. The girls in the classrooms of the teachers who did not like math found math distasteful. This despite both groups' belief that all of their teachers love math. There were no differences in the attitudes of the boys.

This study points out how negative attitudes toward math are passed on to female students. Because elementary school teachers are as likely to be science phobic as math phobic, Karp's study suggests that we either need to help elementary teachers feel more comfortable with science or have science taught by science specialists in the elementary school.

As the Karp study indicates, teacher attitudes toward math and science have an impact on girls. We must work with elementary and middle school female teachers, for whom science is not a familiar and welcome event, to help them learn what we hope the girls in school will learn: Science is for females.

Equal Treatment or Equal Outcome?

When thinking about science participation of girls, educators must confront the dilemma of equal treatment versus equal outcome. The former does not always result in the latter. For schools to boast gender-equal science outcomes, it is sometimes appropriate to treat the sexes differently while at other times it is more helpful to make no distinctions.

Studies that document the ways teachers and schools treat girls report two seemingly contradictory patterns. First, classroom activities, teaching patterns, and curriculum materials rarely include the experiences of girls, the language of girls, and the lives of girls. Second, even though male lives and preferences are the norm in schools, we rarely help girls learn the skills to excel in these behaviors.

For instance, recent work on females has pointed out that girls are more likely to feel comfortable

in cooperative learning activities than in competitive ones (AAUW, 1992). Using this finding to guide practice can result in different responses. One is to change classroom organizing and interaction patterns so that they are cooperative, making the classroom more inviting and comfortable for girls. A second is to coach girls in competitive practices, helping them learn aggressive argumentation and comfort with right-wrong questioning. A third response is to do both, and it is on such a foundation that this article is built.

Greenberg (1978) argues that schools remediate the deficits of males, while leaving the weaknesses of females unattended, through the use of formal and informal curricula. In her analysis, females and males come to school at different places in their development. For instance, girls arrive having had more practice in small or fine motor tasks, while boys have more skill in large or gross ones. The formal curriculum, in which all students must participate, is primarily built around learning what boys do not know or cannot yet do—small motor skills, impulse control, polite behavior, drawing, cutting, and verbal interaction. As a result, boys are forced in the formal curriculum to learn new skills, while girls get practice in skills they already have.

The informal curriculum, which is elective and takes place at recess or during free play, allows students to participate in activities with which they feel comfortable. Boys choose socialized "boy play," which is largely not part of the formal curriculum, and girls select stereotypic "girl play," which is. As a result, boys have more variety in their activities while at school.

Playing with blocks is a good example of how the formal and informal curricula can fail girls. Playing with blocks, an activity related to early spatial development, is rarely assigned to the formal curriculum in early childhood programs. Instead, it is an elected activity allowed in free play or recess. Boys, who come with more experience in block play than girls, choose blocks in free time. Girls do not. Thus, girls are deprived of an opportunity to learn an important critical thinking and organizing skill, while boys expand their skills by electing an activity that adds to the formal curriculum.

Another example of how equal treatment and equal outcome are often at odds can be found in the research on single sex schools and classrooms. What a synthesis of these studies tells us is that the best environment for females is an all-girl school, while the best place for boys is a coeducational setting (Shakeshaft, 1986). While a mixed-sex school can be as good for girls as for boys, until we change teaching patterns and stereotypic practices about girls, it is not likely to be. As a result, a few schools have recently had considerable success teaching science and math to girls in all-girl classes, while working with boys in mixed-sex groups. Until we change the gender imbalance in the teaching practices in schools, this strategy should continue to be used.

Conceptualizing the entire learning environment that children experience and then trying to understand how what we teach in schools supports and adds to what children already know, asks educators to include gender comfortable and gender challenging activities in the science classroom. We need to help girls learn independent, boundary breaking skills, while at the same time letting them have some opportunity to elect collaborative environments and problem-solving experiences.

Summary

Reform strategies that do not pay attention to the different ways boys and girls think about and participate in science are not likely to succeed. Building confidence, making science familiar and relevant, helping girls learn test-taking skills, working with teachers to change attitudes and teaching practices, and helping girls overcome their stereotypes both about scientists and themselves will insure that "science for all Americans" includes girls.

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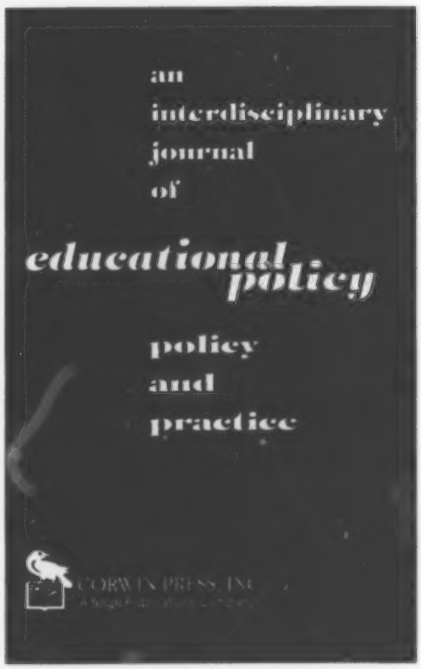

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The members of the School Science and Mathematics Association (SSMA) are educators from the range of kindergarten through graduate school who have an interest in science and mathematics education. The Association, formerly the Central Science and Mathematics Association, has existed and published its journal since 1901. It is incorporated in Illinois as a not-for-profit educational organization.

SSMA's primary focus is the integration of science and mathematics content in K-12 schools. The Association is interested in all kinds of dialogue relating to the improvement of instruction in the two subjects. Its often-quoted Journal, *School Science and Mathematics*, has been published continuously since 1901. There are eight monthly issues per year, October through May. Articles range all the way from practical classroom activities to research pieces. Research papers, when presented, must relate to practical use by classroom teachers. The Journal regularly includes feature articles, editorials, mathematical problems with solutions in subsequent issues, historical notes about the Association, book and software reviews, Association news, and an annual index (December). In 1995, the Journal reached 2000 libraries and 1100 members worldwide. Special focus issues have included "Career Education" (April 1976), "Science and Mathematics for Early Childhood" (January, 1982), and "Integrated Mathematics and Science" (January, 1994).

The Association also publishes a Newsletter for its individual members, *SSMArrt*, which is published four times a year. In addition, occasional monographs include separate series in classroom activities and topics-for-teachers. Classroom Activity titles include *Problem Solving with Number Patterns* (1987), *Activities for Teaching K-6 Math/Science Concepts* (1989), and *Spreadsheets in Mathematics and Science Teaching* (1992). "Topics" titles include *Interactions of Science and Mathematics* (1980), *A Bibliography of Integrated Science and Mathematics Teaching and Learning Literature* (1992), and *Wingspread Conference Plenary Papers* (1994).

Each year the Association holds its annual meeting and national conference in a different state, usually in conjunction with a local state science- or mathematics-teachers association. SSMA has been heavily committed to developing local state organization through these joint ventures. Several state conferences have tripled in size and science and mathematics groups worked together jointly first time as a result of these SSMA involvements.

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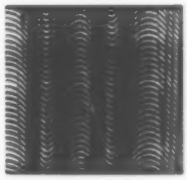

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